COMPARATIVE STUDIES OF THE EFFECT OF SOIL- AND LEAF-APPLIED NUTRIENTS ON SOME CROP PLANTS

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CERTIFICATE

This is to certify that the thesis entitled: "Comparative studies of the effect of soil- and leaf-applied nutrients on some crop plants" submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Botany, is a faithful record of the bonafide research work carried out at the Aligarh Muslim University, Aligarh, by Mr. Abdul Khalique under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

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C O N T E N T S

C H A P T E R I

INTRODUCTION

Environmental factors play a very important role in the realisation of the genetic potential of a plant. They affect growth, development, yield and grain quality of cereals. Among these factors, nutrition is of prime importance. Investigations carried out by many workers show that any disbalance in nutrition may be harmful for plant growth and may also prove uneconomical. For the best growth and development of a plant a definite proportion of the essential nutrients is required. It is also known that for different crop plants different doses of fertilisers are needed as their utilisation capacity varies. This variation has been noted to be more sharp among the various species of a genus than among different genera in certain cases (Millikan, 1961). It, therefore, becomes necessary that the amount of nutrients required by various species, and even varieties, of plants should be known so that their potential may be fully exploited for obtaining maximum yields.

Much work has been carried out on the nutritional requirements of different crop plants. Most of this work is on macronutrients, particularly NPK, because these have been known longer to play a major role in various plant biosyntheses.

It is an established fact that one of the many important roles of nitrogen is in protein synthesis which ultimately affects the grain quality of cereals. Likewise, phosphorus is "involved in practically every synthetic reaction of the cell" (Hewitt, 1963 p. 148). It is also known to influence grain quality. For example, Afridi and Samiullah (1973 b) have established that the malting quality of barley is improved by judicious application of phosphorus to the soil.

Since ancient times, farmers have applied fertilizers only to the soil but recently spray application of fertilisers has attracted the attention of the entire farming world and is being practised on a wide scale. The development of highly soluble fertilizers, such as urea, and of the machinery for spraying insecticides and fungicides, has facilitated the application of nutrients in the form of spray. The nutrients generally applied to the leaf are absorbed, translocated and subsequently utilised in a similar way as the nutrients applied to the roots (Volk and Mc Auliffe, 1954). During the last two or three decades radio-tracer technique has been extensively used by farm scientists studying nutrition through foliage. The use of radio-isotopes has enabled them to trace the rate of entry of nutrients into the leaves, their translocation to, and metabolic roles in, various plant organs.

Foliar application of nitrogen and phosphorus provides an economic and efficient method of fertilization. The most widely used form of nitrogen sprayed on cereals is urea due to its high solubility, high nitrogen content and relatively low damage caused to the leaves. However, the results obtained by different workers are contradictory. Whereas it has been reported that spray of nitrogen is superior to soil application (Narayanan and Vasudevan, 1959; Sadaphal and Das, 1966); others claim that it is equally good (Foy et al. 1953) and still others, that it is less effective than normal soil application (Simkins, 1959). It may be pointed out that the effect of urea sprays on the grain quality has generally been found to be favourable (Reeves, 1954; Fuleki and Nagymihaly, 1956; Finney et al. 1957; Pavlov, 1960; Pinevic, 1960). Comparatively much less work has been done on the foliar application of phosphorus (Samiullah, 1971). Like nitrogen, however, phosphorus is easily absorbed and utilised from sprays and the amount required is much less than for soil application (Boynton, 1954).

As mentioned earlier, many workers have investigated the nutritional requirements of fruit trees, vegetable crops, sugar beet, sugar cane, cereals and other crops plants. At Aligarh, the NPK requirements of barley varieties NP 13, NP 21 and NP 104 have been investigated by Safaya (1971). The comparative effect of phosphorus, applied to the soil and to the leaves, on the nutrition, growth and malting quality of barley variety NP 13 has been worked out in detail by Samiullah (1971). However, many new high yielding varieties have been evolved since, making a re-investigation desirable. It may be added that no such work has been done on 'Kharif' (ummer) crops, such as maize which is an important crop of Uttar Pradesh (India). It is noteworthy that investigations on the nutritional requirements of leafy vegetables have also not been undertaken.

In the present investigation three varieties of barley viz. RS 6, IB 226 and K 572/10, three of maize viz. Ganga-5, Ganga-7 and Kisan, and one of lettuce (Suttons Golden Ball) were selected for their high yielding capacity as well as other desirable qualities and experiments were conducted to study:

1. The effect of basal and spray nitrogen and phosphorus on the growth, yield and NPK content of the three barley varieties in sand culture in pots.

2. The effect of basal and spray nitrogen and phosphorus on the growth, yield and NPK content of lettuce in soil culture in pots.

3. The response of the three varieties of maize, regarding yield and grain quality, to various levels of nitrogen and phosphorus applied to the soil and sprayed on the leaves under field conditions.

4. The effect of various doses of spray phosphorus on the yield and grain quality of three varieties of maize, grown in the field with various doses of basal nitrogen and phosphorus.

The results of these experiments and the conclusions drawn from them are presented in this thesis.

C H A P T E R II

REVIEW OF LITERATURE

Mineral nutrition of plants

Ever since the birth of civilization, man's dependence on plants has increased more and more, so has his inquisitiveness about their needs and well being. Bould (1963) credits Cato (234-149 B.C.) as one of the pioneer writers on the nutrition of plants. The collective wisdom of Roman agricultural writers over the centruries was condensed into one volume around 1240 A.D. by Crescentius and reproduced through many editions, inspiring subsequent writers in several European countries who came out with new ideas that attracted the attention of those interested in agriculture until the 16th century (Russel, 1950).

It is not the intent of the present review to consider in detail the developmental history of the science of plant nutrition. Suffice it to note that the essentiality of the major elements (macronutrients) for the growth and reproduction of plants was established by 1860 and it took almost another century to add the micronutrients to the list (Stiles, 1961).

Foliar fertilization

The application of salt solutions to the aerial parts of the plants has attracted the attention of farm scientists rather recently although, according to Bould (1963), the technique was first used by Forsyth in 1803. Another early report on the foliar absorption of mineral nutrients by Gris appeared in 1844 (Wittwer and Teubner, 1959). This was followed by the works of Mayer (1874) and Bohm (1877) in the last century.

With the discovery of micronutrients and the recognition of nutritional disorders caused by their deficiency, attention was focussed on corrective measures that included foliar application of salts of these essential elements that could be readily absorbed through the tops. The convenience afforded by the technique, together with the saving of the nutrients, made it more attractive than the alternative methods, particularly the one requiring application in the soil to standing crops.

Research on foliar nutrition has been greatly facilitated since 1951 by the use of radioisotopes which permit accurate measurements of uptake and transport, and allow a distinction between nutrients absorbed by the foliage and those simultaneously taken up by the roots (Wittwer and Lundahl, 1951; Silberstein and Wittwer, 1951; Boynton, 1954).

Foliar application of nitrogen

The practice of spraying nitrogenous salts in dilute form over the leafy surface of fruit trees dates back to 1914 (Ballard and Volck, 1914; Lewis and Allen, 1914) and it was in common use during and after the Second World War (Boynton, 1951).

As regards cereals, Kuthy *et al.* (1952) found an increase in grain yield and protein content of barley and wheat when nitrogen was sprayed on the leaves, late application of nitrogen seemingly being more favourable.

Thorne and Watson (1952, 53) sprayed winter wheat at ear emergence with 3.0 percent ammonium nitrate at 100 gal. per acre. They, however, noted that the treatment had the same effect on yield and on the nitrogen content of grain and straw, as supplying the same solution to the soil at the same time. In sugar-beet plants, the nitrogen uptake from 3.0 percent ammonium nitrate or an equivalent urea solution, applied in September as six sprays, each of 100 gal. per acre, was twice that obtained from similar solutions applied to the soil. Of the nitrogen applied in the leaf sprays, whether as ammonium nitrate or urea, 73.0 percent was recovered in the plant and 29.0 percent was converted to leaf protein. In another experiment, they found that nitrogen uptake from four 3.4 percent urea sprays, each applied at 100 gal. per acre and from one spray of 54.7 percent urea at 25 gal. per acre, did not differ significantly, although the concentrated spray caused some leaf scorch.

Hinsvark *et al.* (1953) tested the degree of injury by solutions of different urea concentrations to six species of crop plants grown under green house conditions. They found that leaves of cucumber were subject to greater injury from lower concentrations of urea than those of bean, tomato, corn, celery and potato. The last two species were the most resistant to injury even by high concentrations of urea.

Foy *et al.* (1953) reported that the spray of urea at low rates and low concentrations on the leaves of maize had a beneficial effect on the yield of the plant.

Anma *et al.* (1954) noted that spraying with 0.5 to 3.0 percent solutions of "Nugreen" (a urea product) at rates of up to 34 lb/ha, was superior over an equivalent amount of top-dressed ammonium sulphate in increasing the protein content of barley and wheat but not in increasing grain yields.

Reeves (1954) reported that when urea was sprayed on wheat in late winter and early spring, the yields were increased but most significant improvement occurred in the baking quality of the grain. The percentage of mottled grain in a translucent grained variety was also decreased.

Medenis (1954) sprayed clover, rye, spring wheat, flax and meadow grasses, before or at flowering, with 1.5 to 3.0 kg N/ha and found an increase in the yields. A general improvement in seed quality was also observed particularly with sprays at flowering time.

Boynton (1954) reviewed the literature on nutrition by foliar application extensively and noted that nitrogen and other nutrients were absorbed by, and translocated from, the leaves rather rapidly. He generalized that young leaves and leaves on relatively young branches absorbed more nutrients than older ones. He also noted that the solution penetrated both through the cuticles as well as stomates. The former were found to be more effective for penetration over longer periods while the latter were of greatest significance initially and for short duration only. He further pointed out that the contact angle of the liquid determined its ability to wet the leaf surface. The contact angle could be reduced by the addition of wetting agents.

However, it is noteworthy that hardly any mention is made in this review of the application of nitrogen (or phosphorus) sprays on cereal crops.

Juarez and Swanson (1955), working on wheat, sprayed the plants 15 days before, 15 days after and at flowering with urea at low, moderate and high concentrations. They reported that the results were not statistically significant, but pre-flowering applications at low and moderate concentrations increased grain yields, and post-flowering applications at all concentrations improved protein content of grain.

Petinov and Pavlov (1955) found that, in spring wheat, high doses of spray nitrogen increased the protein and gluten content of the grain, an effect offset by increased irrigation.

However, Gardner (1955) reported that there were no advantages, either in terms of dry weight or crude protein, to be gained by applying nitrogen, as a urea spray, to winter wheat.

Yatazawa and Namiki (1955), in studies with wheat, applied 2 percent solutions of urea containing N^{15} as foliar spray 5 days before heading. Fourteen days later they found that 8.6 percent of the applied urea was present in the ears, 27.0 percent in the flag leaves, 8.5 percent in the stems and roots and 21.5 percent in the leaf sheaths of the treated leaves.

Thorne (1955a) reviewed the literature on the uptake of nitrogen, phosphorus and potassium from leaf sprays by crops. She concluded that, from a critical point of view, pot experiments were preferable to field experiments as, in the former case, it was easier to prevent the sprayed nutrients from reaching the roots by falling over the soil. She also mentioned that much more work had been done with nitrogen sprays, in the form of urea and inorganic salts, on fruit trees than on cereals and grasses. Moreover, the few references about graminaceous plants cited in the review, including her own, failed to establish the superiority of the spray technique to soil application of nitrogen.

Finney _et al_. (1957) investigated the effect of foliar spray of urea solution on yield, protein content and protein quality of Pawnee wheat. They found that yield was increased by sprays of high concentration applied before flowering. The protein content was increased from 9.3 to 16.1 percent by spray during the fruiting period. A single spray of urea at flowering also increased grain protein but by 4.4 percent only. Much greater increases in protein content (10.8 to 21.0 percent) were obtained with repeated sprays during fruiting. Quality of protein varied with the concentration, timing and number of urea sprays.

Reuterberg (1957) investigated the utility of different compounds of nitrogen for foliar fertilizing of oats, green beans and potato. He reported that, with the application of 0.25 percent nitrogen to the leaves, yields and dry matter production of oats were increased by urea, ammonium nitrate and potassium nitrate. All these salts, as well as ammonium sulphate and sodium nitrate, increased the protein content of the crop.

Klingman (1957) reported that spray applications of urea or ammonium nitrate at a rate of 40 lb N/acre to maize plants 18 inches high resulted in yields equal to those from solid ammonium nitrate applied at a rate of 80 lb N/acre as a side dressing and gave good control of weeds.

Krzysch (1958) studied the effect of increasing concentration of the sprayed fertilizer from 0.15 to 0.6 percent nitrogen and found that the total yields of oats (grain and straw), and the nitrogen content of the grain, were increased by these sprays.

He also noted that the best time for spraying was at the booting stage.

Kuthy _et al_. (1959), while working on winter barley which had received calcium ammonium nitrate containing 56 kg N/ha in February, reported that spraying the same fertilizer as a 10 percent solution at the rate of 62 kg N/ha at the end of May, resulted in an increase in grain and straw yields by 20 and 45 percent, respectively, and caused an increase of 100 kg/ha protein in the grain and 75 kg/ha protein in the straw.

Wittwer and Teubner (1959) reviewed the work done on many aspects of foliar application of mineral nutrients including the mechanism and factors affecting absorption, transport and mobility, metabolism, leaching and crop responses. In this extensive review considerable attention was paid to urea as the most widely used material in nitrogenous sprays. The reviewers, however, noted with surprise that so little was known concerning the mechanism of absorption and utilization of this important fertilizer, particularly so in the case of cereal crops. Although it was well established that nitrogen (either as urea or as inorganic salts) was readily absorbed through the leaves, there were few references which showed positive yield or growth responses above those which could be procured by the most effective soil fertilization. Data on surfactants were inconclusive and "safening agents", including sucrose and some magnesium salts used for reducing foliar injury from urea, were found to depress the rate of its uptake rather than reduce urease activity which had been suggested to limit uptake. In this connection it may be mentioned that the role of urease in urea uptake by leaves of various plants had been shown by these reviewers to have started a controversy that required resolution.

This review is a valuable publication on foliar nutrition as it not only cites but also gives a critical assessment of most of the relevant information. Moreover, it includes broad hints about future lines of research, particularly from the point of view of the agro-technical efficiency of the method. It seems to have evoked considerable interest among research workers on the nutrition of cereal crops as is evidenced by a spurt of publications in the next decade or so, discussed below, on foliar feeding of these important crops by nitrogen, particularly in the form of urea.

Pinevič (1960) reported that the application of nitrogenous fertilizers during the earing and ripening stages of wheat increased the grain yield and the percentage of protein in the grain. The application of the ammonium and urea nitrogen at a late stage decreased the content of gliadin in the grain and increased the glutenin content.

Pavlov (1960) noted an increase in protein content in maize due to the spray of 4 to 5 percent of urea, whereas Petinov and Pavlov (1960) reported an increase of 48 percent protein in the grain of maize when plants were sprayed with 3 to 6 percent urea.

Sadaphal and Das (1966) reported that, in wheat, foliar application of urea caused an increase in the number of grain per ear and 1,000 grain weight. Concentrations of urea from 1 to 6 percent increased the total yield of grain, an increase of 52 lb/acre being recorded with each increase of 1 percent concentration. Urea spray also increased the protein content of the grain. The range of increase in protein varied from 18 to 34 percent. Spraying at flowering enhanced the rate of accumulation of protein in grain.

Shrivastava (1968) reported that foliar application of urea at a low dose of 22.4 kg N/ha decreased the number of ears per plant and the number of grains per ear by 3.13 and 12.32 percent respectively, although 1,000 grain weight was increased by 3.27 percent as compared with application to the soil. At 44.8 kg N/ha, the effectiveness of foliar-applied nitrogen was greater than at the lower rate due apparently to an increased number of ears per plant and grains per ear.

Randhawa *et al.* (1969) noted that in wheat variety G-306, application of urea at 33 kg N/ha increased the average grain yields to 3224 to 3466 kg/ha and the grain protein content to 12.2 to 14.2 percent compared with 2902 kg and 11.2 percent respectively for controls given no nitrogen. Higher yields and higher protein content were obtained by applying 11 to 22 kg N/ha to the soil and the remainder as a foliar spray than by applying the full dose to the soil. Increased yields were attributed to an increase in the number of grain per ear and in 1,000 grain weight.

Singh and Saroha (1970) studied the time and method of urea application to maize and reported a significant increase in grain yield (29 percent), stover yield (49 percent) and nitrogen uptake (44 percent) when urea (60 kg in preference to 40 kg N/ha) was sprayed in three equal instalments (at first irrigation, knee-high stage and tasselling) rather than applied conventionally (50 percent each at sowing and tasselling). The treatment had no adverse effect on protein.

Zhemela and Lebedeva (1970) studied the effect of foliar spraying with nitrogen at different times on grain quality of winter wheat. They noted that spraying with urea, preferably during earing to the beginning of the milky stage, improved the protein and gluten content of the grain as well as flour strength and baking properties.

Sharma (1970) grew the dwarf wheat variety, Kalyan Sona, with a basal dressing of 40 kg N plus 75 kg P_2O_5 plus 80 kg K_2O/ha. When additional nitrogen at 40, 75 or 80 kg N/ha was applied to the soil or as a foliar spray at 30, 50, 70 and 90 days after sowing, the foliar sprays were found to increase average yield by 0.74 t grain/ha, compared with soil application. The highest average yields (5.79 t /ha) were obtained when the nitrogen was applied at 90 days after sowing as a foliar spray. The protein content of grain increased progressively with delaying nitrogen application from first to last date, foliar spray proving superior to soil application.

Mehrotra and Lal (1970) reviewed the available literature mentioning the results of the investigations on various crops undertaken by their group at Kanpur, particularly from the point of view of production efficiency (net return/kg N added). They noted that in 1963-65 highest potato yields were obtained by spraying urea at 10 kg N/ha combined with 70 kg N/ha applied to the soil. The same dose of spray proved more efficient with even as low a quantity of solid fertilizer as 30 kg N/ha when compared with the results of applying 80 kg N/ha to the soil alone. Similar results were obtained at Danpur (Bulandshahar) and Supi (Nainital) where 100 kg N/ha applied half to the soil and half by spray gave better yields than when the total quantity was applied either to the roots or to the leaves alone, suggesting that urea nitrogen could at best supplement, but never substitute for soil application in potato. In 1965-66 significantly superior yields of green leaves of spinach were obtained by a combination of 30 kg N/ha through soil plus 30 kg N/ha as six urea sprays applied twice before each cutting. Even spraying urea at the low rate of 30 kg N/ha proved better than double this dose applied to the soil and resulted in highest production efficiency. In experiments on cabbage (1966-67), they found that plants receiving a basal dose of farm yard manure with 20 kg/ha each of nitrogen, phosphorus and potassium showed better yields when 10 or 20 kg N/ha as urea was sprayed in split doses as compared with the application of up to 20 kg N/ha through the soil, the highest production efficiency being achieved with urea sprays at the rate of 20 kg N/ha. In 1966-67 experiments, they noted that, in maize, the highest grain yield was obtained by the application of 40 kg N/ha, half through soil and half by spray as urea, the combination proving to be the most profitable from the point of view of net return per kg of nitrogen applied.

Rameshwer Reddy and Suryanarayana Rao (1971) reported that the protein content of Mexican (dwarf) wheat varieties was influenced by the application of nitrogen by different methods. Spray of urea after flowering caused an increase in protein, presumably due to more efficient utilization of nitrogen from spray as compared to soil treatment.

Seth and Prasad (1971) studied the relative efficiency of soil and foliar application of nitrogen in barley under rainfed conditions. They noted that the foliar application of 16.8 kg N/ha as 3 percent urea solution gave grain yields (2.15 t/ha) similar to those obtained by the application of 33.6 kg N/ha at sowing (2.17 t /ha); 33 kg N/ha applied in two equal split dressings at sowing and as a foliar spray gave the highest yield of 2.34 t/ha.

Fofanov (1972) noted that, in spring wheat, foliar application of 30 kg N/ha, as thio-urea, increased the protein content by 16 to 17 percent. The smallest increase (7 percent) was recorded for albumins and greatest 26 to 29 percent for glutenins. Application at the early earing or late flowering stage produced the same effect.

Singh and Bains (1973) reported that two levels of nitrogen (25 and 50 kg N/ha) increased the grain yield significantly over the control. The increase (63.6 percent) with the application of nitrogen was owing to the production of more effective tillers and grain per ear. However, the difference between the effect of 25 and 50 kg N/ha was not significant. They also mentioned that nitrogen application 2/3 at sowing and 1/3 at boot stage through foliage gave the highest grain yield and produced bold grains rich in protein content.

Foliar application of phosphorus

Like the spray of nitrogen, application of phosphorus to the aerial organs of plants is known to affect the chemical composition, growth, yield and grain quality of cereals. It may be added that much less work has been done with phosphorus sprays than with those of nitrogen or micronutrients.

The first report of the absorption of phosphorus from a combined spray of nitrogen, phosphorus and potassium seems to be that of Lewis (1936) on lettuce leaves. No attention was, however, paid to the foliar application of this important nutrient until Silberstein and Wittwer (1951), working with bean, maize, squash and tomato grown in pots at low phosphorus levels, reported rapid absorption and translocation of P^{32} from the leaves to all parts of the plants including roots and meristems. In field trials with tomatoes, early yields, but not total yields, were found to be increased significantly by four weekly applications of a 25 millimolar solution of o-phosphoric acid. Considering the quantities used, foliar applied phosphorus was utilized much more efficiently than phosphorus applied broadcast to the soil but the latter treatment gave highest total yield.

Kaindl (1954) published the results of experiments on foliar fertilization of cereals. Using phosphatic nutrients labelled with P^{32} , he noted that wheat and other cereals had two periods during their vegetative growth, when foliar sprays were most effective. One, about a fortnight after sowing, when the growth cycle had not yet started and the other about a month after sowing when the plants were expected to possess maximum vitality. He also observed that spraying in the evening was more effective as the drying process was very slow and dew formation the following morning re-mobilized the dried up nutrients.

He also mentioned that conditions of high humidity promoted leaf intake and that, at least in fruit trees, spraying with water alone after nutrient application might be advantageous. He noted that the combination of soil and foliar fertilization gave higher yields as compared with either treatment alone and that application of fertiliser spray on the lower surface of the leaf was more fruitful than on the upper surface.

The review of Thorne (1955a), mentioned earlier, emphasized the desirability of applying phosphorus through the foliage rather than the soil. None-the-less, it was noted that in practice phosphorus appeared to be applied in sprays much less frequently than nitrogen. This could be either because agricultural crops were believed to require phosphorus early in the growing season when there was only a small leaf-area to retain the spray or due to the relatively low solubility of many phosphorus compounds.

It was also pointed out that little research had been done on the growth responses to phosphorus absorbed through the leaves. However, the mechanism of uptake and the mode of translocation to other plant organs had been worked out in detail employing the techniques of dipping the shoots, painting the leaves, injecting the aerial parts or by spray using various phosphorus-containing solutions. The effect of spray phosphorus on the absorption of soil phosphorus had also been studied in some instances quoted and it was noted to be of little consequence except when the soil was rich in phosphorus when root uptake was reduced.

Rauterberg (1957) noted that, in oats, spraying with 0.35 percent phosphorus as ammonium, potassium or magnesium phosphate increased grain yield of oats more than application of phosphorus fertiliser to the soil did.

In their excellent review, mentioned earlier, Wittwer and Teubner (1959) noted that phosphorus was readily absorbed from the leaves. However, there was no consensus on the effect of wetting agents on its uptake by leaves as it was either reported to be decreased (Swanson and Whitney, 1953; Koontz and Biddulph, 1957; Teubner _et al_. 1957), or to be increased (Fisher and Walker, 1955) or was unaffected (Barrier and Loomis, 1957) by various surfactants. A similar situation existed regarding the effect of pH of the spray solution on phosphorus uptake. However, generally a low pH value (between 2.0 and 3.0) was claimed to favour foliar uptake in comparison with higher values. Similarly, there was difference of opinion regarding the most readily absorbed salt of phosphorus, possibly because of difference in the species of plants studied.

They also concluded, from the evidence considered, that the mechanism of phosphate absorption consisted predominantly either of an exchange or an active absorption process. They also noted that a Q_{10} value approximating 2.0 had been reported for the uptake of phosphorus (Sosa-Bourdouil and Lecat, 1952; Teubner *et al.* 1957).

Discussing the transport and mobility of phosphorus, these reviewers concluded that the initial translocation of phosphate from the leaf through the phloem was an "active" process as it required a source of energy (light or sugar), and as metabolic inhibitors, like dinitrophenol and sodium fluoride, as well as low temperature, retarded it. They cited evidence from one of their own publications (Teubner *et al.* 1957) and from that of Tolbert and Wiebe (1955) that phosphorus was translocated mainly in the inorganic form following P^{32} uptake by leaves, although there were reports of considerable labelling of organic phosphate, including the esters of sugars. In this connection it is noteworthy that Biddulph and Cory (1957) and the Japanese workers, headed by Yatazawa, believed that sugar phosphate esters, e.g. glucose 1-6, diphosphate, played a dominant role in the process.

Regarding the metabolism of foliar-applied phosphorus, mention was made of its utilization in the sugar, lipid and protein metabolism of the plant. In this connection the work of Barrier and Loomis (1957), Biddulph and Cory (1957), Sosa-Bourdouil and Lecat (1952), Teubner *et al.* (1957), among others, was cited.

Datta and Vyas (1967) studied the foliar uptake of P^{32} by maize. They used four different P^{32} labelled phosphates, namely superphosphate (20.56 percent P_2O_5), monocalcium phosphate (60.42 percent P_2O_5), dicalcium phosphate (34.00 percent P_2O_5) and ammonium phosphate (60.40 percent P_2O_5) at 5 lb/acre and found most rapid phosphate uptake at the early stage of growth. They claimed the spray to be eight times as efficient as soil application, thus proving foliar fertilization to be a very economical method, specially under conditions where higher doses remained unutilized by soil application.

More recently, Samiullah (1971) and Afridi and Samiullah (1973a,b) undertook intensive studies to investigate the effect of phosphorus (applied as basal dressing or foliar spray) on the nutrition, growth and malting quality of NP 13 variety of barley. They found that soil, as well as foliar, application of phosphorus decreased the nitrogen and potassium concentration of leaves, whereas soil dressing with phosphorus increased the phosphorus content until the heading stage; but at the milky grain stage a decrease was noted. This was corrected by one or two foliar sprays with a moderate dose (1.356 kg P_2O_5/ha) applied at 70 days or at 70 and 80 days after sowing.

They noted that growth and yield were favourably affected by phosphorus. Considering most of the characteristics studied, the variety showed optimum response to the higher doses of the solid fertiliser (90 and 120 kg P_2O_5/ha) in the presence of 80 kg N/ha. When phosphorus was applied to the leaves by spray, plants grown with a basal dressing of a low dose (30 kg P_2O_5/ha) responded much more than those grown without phosphorus. 1.356 kg P_2O_5/ha sprayed on the tops once at 70 days, or twice at 70 and 80 days, after sowing gave the highest yields.

Lastly they found that phosphorus application to the soil or to the leaves resulted in better quality grain for the purpose of malting. However, spray treatments were found to be superior to soil dressing, spray dose and timing that favoured growth and yield of barley giving the best quality grain for malting. Increasing doses of nitrogen in the soil, like those of phosphorus, favoured 1,000 grain weight. However, contrary to the effect of phosphorus, increasing the dose of nitrogen resulted in higher protein concentration in the grain which, although good for feeding purposes, is considered an undesirable character from the point of view of malting. It was, therefore, suggested that judicious application of fertilizers could ensure high yields of better quality grain suited either for malting or for feed. Stress was also laid on fertilizer economy ensuring high yields and better quality grain through sprays of nominal quantities of phosphorus on plants grown with sub-optimal solid phosphatic fertilizer.

Foliar application of nitrogen and phosphorus

Inspite of the early establishment of the fact that nitrogen sprays were beneficial, at least for apples, and the desirability of foliar application of phosphorus as recommended by Silberstein and Wittwer (1951), not much work has been done on the combined effect of nitrogenous and phosphatic sprays even on fruit trees.

Lewis (1936) seems to be the first to have included phosphorus in a combined spray with nitrogen and potassium on lettuce grown in pot culture. He noted that application of such a solution daily for five weeks increased the phosphorus content of the leaves but not the nitrogen or potassium content. It did not matter whether the solution was applied only to the leaves or to the soil also.

Thorne and Watson (1952) investigated the problem using sugar-beet and found that combined sprays of nitrogen, phosphorus and potassium resulted in increase of 50 percent of nitrogen and potassium content and 20 percent of phosphorus content in the sprayed plants. In comparison, the recoveries of these nutrients when applied to the soil were : nitrogen - 20 percent, phosphorus - 10 percent and potassium - 30 percent.

Pastac (1954) was another pioneer investigator to have studied the combined effect of nitrogen, phosphorus and potassium from the point of view of establishing the optimum formulations and ratios of these three major nutrients for plants.

Thorne (1954) studied the effect of foliar application of nitrogen with phosphorus and potassium on different plants and noted that the sprayed plants had higher nutrient content and dry weight than the controls. In barley, the treated plants developed more tillers but ripened later than the controls.

According to the review of Thorne (1955a) sprays containing nitrogen, phosphorus and potassium were used occasionally. Several commercial mixed fertilisers of high solubility were developed for application in solution to leaves (or soil) and some had been used experimentally (Gillern, 1950; Pirone, 1952; Arvan and Mowry, 1954). The concentration of salts in a mixed spray was, however, limited by their solubility and the danger of scorching, so that several applications might be required to supply the same quantity of a nutrient as could be applied alone in a single spraying or in a single soil dressing. A single spray, therefore, would have smaller effect than a soil dressing unless a given quantity of nutrient applied to leaves was as effective as ten times the quantity applied to the soil, as was claimed by Mednis (1952) in Russia. Other Russian workers (e.g. Matskov, 1949) also reported experiments with mixed sprays, but neither the quantities of nutrients applied nor comparisons with soil applications were given by them.

Thorne (1955b) studied the interaction of nitrogen with phosphorus and potassium applied both in leaf sprays as well as to the soil. She confirmed that, in sugar-beet, the absorption of each of the three nutrients was independent of the presence of the others and that the application of nitrogen or potassium to the leaves increased the uptake of phosphorus from the soil. She also noted that less nitrogen but more phosphorus was absorbed from the spray than from fertilizer. Solid nitrogen fertilizers increased the uptake of foliar-applied phosphorus and potassium, although nitrogen intake remained unaffected by such fertilizer treatment.

Mosolov _et al_. (1956) showed that various combinations of nitrogen, phosphorus and potassium in the spray increased wheat and barley yields. The protein content of wheat and the starch content of barley was also claimed to have been increased by the mixed spray.

Rubin (1956) found that spraying 5 percent aqueous solution containing nitrogen, phosphorus and potassium increased the number of flowers on apple and consequently the yield was increased.

Fuleki and Nagymihaly (1956) reported that sprays of 1 to 5 percent solutions of ammonium nitrate or urea, and of 3 to 9 percent solutions of combined nitrogen, phosphorus and potassium, were totally absorbed by the foliage of maize, the higher concentrations causing some leaf burn from which the crop soon recovered.

Sprays of 1 to 5 percent $Ca(H_2PO_4)_2$ were only partially absorbed by the leaves. Crop development was promoted by repeated spraying with 3 percent mixture of nitrogen, phosphorus and potassium plus Hoagland solution and delayed by spraying with 1 percent urea. The mixed sprays increased the reducing sugars and proteins in the plants but had little effect on the starch content.

Thorne (1957) found that in similar experiments, nitrogen and potassium applied to the leaves of swedes and sugar-beet increased the dry weight of the plants. When phosphorus was applied to the leaves it made no difference in the dry weight, although 80.0 percent of the applied phosphorus was absorbed. In plants with high phosphorus supply to roots and sprayed with sodium phosphate, swedes, but not sugar-beet, showed a decreased absorption by roots, uptake from a lower phosphorus supply to the roots was unaffected. The top : root ratio for phosphorus content per plant was greater for phosphorus absorbed through leaves than for phosphorus absorbed through roots. Increasing the phosphorus supply to the roots increased this ratio for phosphorus absorbed through either of the two organs.

Wittwer and Teubner (1959), while dealing with mixed sprays, reviewed more than a dozen technical and practical publications (mostly by workers in Europe) reporting beneficial results of spraying the complete fertilizers on row crops and small grains, particularly if treatments were made during the later stages of vegetative development or during early flowering and fruiting.

Shereverya (1959) studied the inter-relationship of foliar and root nutrition of winter wheat from the point of view of the absorption and distribution of nitrogen, phosphorus and potassium and the consequent effect on the final yield of the crop. It was noted that the change in the pattern of the distribution of these macronutrients in the over-ground organs of the plants were due not so much to foliar absorption itself as to the influence of the latter on their uptake by the root system. The positive effects of the foliar applications on root nutrition could become negative, depending on the moisture level, on the amount of nutrients in the soil and on the form of nutrients applied, particularly nitrogen. The increased rate of uptake of the nutrients by roots as a result of foliar application also increased the final yields of wheat. Under conditions that induced a reduction in root absorption yields were also decreased.

Barat and Das (1962) reported that the uptake of foliar applied nitrogen and phosphorus by maize grown in pot culture was significantly greater than when these nutrients were applied to the soil. Phosphorus application increased the nitrogen content whereas nitrogen application depressed the phosphorus content.

De and Singh (1963) reported that the application of nitrogen, phosphorus and potassium, as leaf spray, was more economical and practicable for potato growing than normal soil-dressing. The fertilizer dose required was as low as one-fourth or even one-fifth of the quantity normally required for soil application and considered to be sufficient for normal yields. Nutrition by foliar spray was found to be easier under the hilly conditions of their experiment than application of fertilizers to the soil. However, Dargan and Singh (1964) failed to find any enhancement in yields due to foliar-applied phosphorus in cotton plants.

Bodade (1964) conducted experiments on sorghum in heavy black soils and reported significantly higher response to foliar application than to soil application. The yield obtained with the treatment which received half of the quantity of soil applied nutrient as foliar spray was more than with the treatment receiving the full dose through soil application. It was observed that foliar application could thus help save fertilizers by fifty percent.

Mukherjee *et al*. (1966) reported similar results from their experiment conducted to compare the efficiency of foliar application with soil fertilization in potato. They observed that when half the dose of nitrogen and phosphorus was applied to the soil at the time of planting and the remaining half was later sprayed over the leaves, the nitrogen and phosphorus content per plant was increased by 29.0 and 37.0 per cent, respectively, as compared with plants receiving the full fertilizer dose in the soil at the time of planting.

Pandey and Misra (1969) noted that an split application of 90 kg N/ha plus 180 kg P_2O_5/ha, applied half to the soil and half by spray at 30, 45 and 60 days after sowing, maximized the tuber yield in potato and proved more economical than a single application of the same quantity of fertilizers either to the soil or to the leaves alone.

C H A P T E R   III

MATERIALS AND METHODS

The experiments reported and discussed in this thesis were conducted during the years 1971-74 in pots or fields at the Aligarh Muslim University Botanical Garden, Aligarh (Uttar Pradesh). The details of each experiment are given below:

I. Pot experiments

A. Sand culture

A sand culture experiment was conducted during the 'Rabi' i.e. winter season 1971-72 on three high yielding and high protein varieties of barley (*Hordeum vulgare* L.) namely, RS 6, IB 226, and K 572/10 to compare the effect of basal and foliar application of nitrogen and phosphorus. 25 cm clay pots, each lined with a polythene sleeve of the appropriate size, and filled with 7 kg of acid-washed sand, were used for raising the plants. The lower end of the sleeve was passed through the bottom hole of the pot and folded loosely below it to allow drainage and ensure aeration. This arrangement had been found to work satisfactorily at Aligarh for protecting the plants, and the sand in which they were grown, from becoming contaminated from outside the pots.

Healthy seeds of uniform size of each of the three varieties were selected and surface sterilized with ethyl alcohol for five minutes and washed thoroughly with de-ionized water before sowing. Ten seeds were sown in each pot at a depth of about 2.5 cm on 25th November, 1971.

The experiment was based on a simple randomized block design. Nutrient solutions (Table 1 and 2) were prepared according to Hewitt (1966). The pH of the solutions was adjusted between 5.8 and 6.8.

The number of treatments was 14 for each variety (Table 3). Each treatment was replicated thrice. The plants were thinned after four weeks leaving five of the more/vigorously growing seedlings of uniform size per pot. 500 ml of appropriate solution was added daily to each pot but when the requirement increased due to the growth of plants, nutrient solutions were applied twice daily.

The plants were sprayed at 4th and 8th week with 2.0 ml of 0.78 percent aqueous solution of sodium dihydrogen orthophosphate and/or 2 percent urea taking care that none of the sprayed solution fell on the sand in the pots. The controls were sprayed with de-ionized water only.

Methods of observation and analysis

Observations with regard to growth, yield and NPK content of the 3 varieties of barley, as influenced by different nutrient

Table 1. Concentrations of the Standard Stock Solutions of macro- and micro-nutrients used for sand culture (Experiment 1).

Macronutrients	Percent
$Ca(NO_3)_2$ (anhydrous)	32.8
KNO_3	20.2
$MgSO_4$, $7H_2O$	18.4
$CaCl_2$	22.2
K_2SO_4	08.7
NaH_2PO_4, $2H_2O$	20.8
Fe citrate, $3H_2O$	05.98
<u>Micronutrients</u>	
$MnSO_4$, $4H_2O$	02.23
$CuSO_4$, $5H_2O$	00.25
$ZnSO_4$, $7H_2O$	00.29
H_3BO_3	01.86
$(NH_4)_6Mo_7O_{24}$, $4H_2O$	00.088

Table 2. Composition of nutrient solutions containing full and half concentration of nitrogen and phosphorus used for sand culture (Experiment 1).

Nutrient	Quantity of standard stock solutions (Table 1)	
	Full N and P (ml)	Half N and P (ml)
$Ca(NO_3)_2$ (anhydrous)	2.0	1.0
KNO_3	2.0	1.0
$MgSO_4$, $7H_2O$	2.0	2.0
$CaCl_2$	0.0	1.0
K_2SO_4	0.0	2.0
NaH_2PO_4, $2H_2O$	1.0	0.5
Fe citrate, $3H_2O$	0.5	0.5
Micronutrients	0.1	0.1
De-ionized water	992.4	991.9
	1,000	1,000

Table 3. Schedule of basal and spray application of nitrogen and phosphorus for sand culture of barley (Experiment 1).

Treatment	Basal	Spray	Time of spray (weeks after sowing)
T_1	Full N + Full P	De-ionized water	4/8
T_2	"	P	4
T_3	"	N	4
T_4	"	P + N	4
T_5	"	P	8
T_6	"	N	8
T_7	"	P + N	8
T_8	Half N + Half P	De-ionized water	4/8
T_9	"	P	4
T_{10}	"	N	4
T_{11}	"	P + N	4
T_{12}	"	P	8
T_{13}	"	N	8
T_{14}	"	P + N	8

environments, were taken in accordance with the recommended procedures which are briefly given below:

1. <u>Sampling technique</u>

To study growth and development, samples were collected at two stages of growth, namely, heading and milky grain stage. All the five plants growing in a pot were collected at each stage of growth.

2. <u>Growth assessment</u>

The following growth characteristics were studied according to recommended procedures:

(i) Shoot length
(ii) Tiller number
(iii) Leaf number
(iv) Fresh weight
(v) Dry weight

Whereas the fresh and dry weights would account for total productivity in terms of increase in volume, weight and dry matter accumulation, shoot length and tiller number would be a measure of meristematic activity and the increase in the number of leaves at different stages of growth would give some idea of differentiation (Gregory, 1937).

3. Yield assessment

Yield characteristic studied are given below:

(i) Ear number per plant

(ii) Ear weight per plant

(iii) Grain weight per plant

(iv) Straw weight per plant

4. Leaf analysis

Leaf analysis is now an established practice for assessing the nutritional status of plants, including cereals (Lundegardh, 1951). In the present work, the total nitrogen, phosphorus and potassium concentrations of fully mature leaf laminae were determined at the two selected stages of growth.

After studying the vegetative characters, the samples were cleaned and kept in an oven at 90°C and dried overnight. Dry weights of the samples were taken. The leaf blades were separated from the stems discarding the leaf sheaths. Each leaf sample was ground to a fine powder with the help of a grinder, sieved through a 40 mesh screen, stored in a screw-capped polythene tube, labelled and kept for analysis. While collecting the leaf blades, care was taken to exclude the dead and decayed leaves.

Digestion was done by the method of Lindner (1944) with a slight modification. This is summarized below:

Before weighing the leaf powder for digestion, a sufficient amount was spread out in a thin layer on a clean sheet of paper and dried overnight at 70°C in an oven. The dried samples were taken out and kept in a desiccator for a while. 100 mg of each sample was weighed and transferred to a 50 ml Kjeldahl flask carefully. 2 ml of chemically pure sulphuric acid was added and heated gently on a temperature-controlled heating assembly till the sample was broken down and partially dissolved. The heating was continued for about two hours in order to reduce the leaf nitrates completely by the organic matter. Dense fumes were given off at this stage and the contents turned black. The flasks were cooled for 10 minutes. After cooling, 0.5 ml of chemically pure 30 per-cent hydrogen peroxide was added and the solution was heated again. Dense fumes began to come out and the contents changed from black to colourless. After heating for about fifteen minutes, when the fumes cleared off, the contents were again cooled. If the contents became light yellow then four drops of hydrogen peroxide were added drop by drop and the solution heated again. At this step of the process, the light yellow contents became colourless. Care was taken in the addition of hydrogen peroxide because its excess might oxidize the ammonia in the absence of organic material. When the contents in the Kjeldahl flasks became perfectly colourless, they were diluted with double distilled water and transferred, with five or six washings, to 100 ml volumetric flasks and made up to volume.

(i) Nitrogen. Total nitrogen in leaves was estimated after Nesslerization. A 10 ml aliquot of the peroxide digested material was transferred to a 50 ml volumetric flask. 2 ml of 2.5 N sodium hydroxide was carefully added with the help of a microburette to partially neutralize the excess of acid. 1 ml of sodium silicate solution was also added to prevent turbidity. The volume was made up to mark. 5 ml of this solution was pipetted into a test tube marked at 10 ml. 0.5 ml of Nessler's reagent was added drop by drop and the tube shaken after adding each drop. Water was added to make up the volume to 10 ml. The contents were allowed to stand for five minutes to allow for maximum development of colour. The solution was then transferred to a colorimetric tube and the optical density read at 525 nm on a "Spectronic 20" colorimeter. A blank was run with each sample. The reading of each sample was compared with a calibration curve, obtained by using known dilutions of a standard ammonium sulphate solution.

(ii) Phosphorus. Total phosphorus was estimated by the method of Fiske and Subba Row (1925). Briefly, a 5 ml aliquot of the original peroxide-digested solution was taken in a test tube marked at 10 ml. 1 ml molybdic acid (2.5% ammonium molybdate in 10 N H_2SO_4) followed by 0.4 ml of 1:2:4 aminonapthol sulphonic acid was added carefully when the colour turned blue. Water was then added to make up to the volume. After waiting for five minutes, the blue coloured solution was transferred to a colorimetric tube and the optical density read at 625 nm on a "Spectronic 20" colorimeter. A blank was run with each sample. The phosphorus content of each sample was obtained by comparing its optical density with a calibration curve plotted by taking known dilutions of a standard solution of monobasic potassium phosphate.

(iii) Potassium. Potassium was estimated flame photometrically. 1 ml of the digest was taken and read at 768 nm. A blank was run side by side. The readings were compared with a calibration curve plotted for different dilutions of a standard potassium sulphate solution.

B. Soil culture

The object of this experiment was to study the effect of foliar-applied nitrogen and phosphorus on the vegetative characteristics of lettuce (*Lactuca sativa* L.), Variety Suttons Golden Ball, with particular emphasis on the total vegetative yield.

The experiment was conducted during the year 1972. The lettuce seeds were sterilized by ethyl alcohol for about five minutes and then washed thoroughly with de-ionized water. The seeds were sown in trays containing acid-washed sand. After four weeks, one healthy seedling was transplanted to each clay pot of 25 cm diameter, filled with 8 kg of soil. The physicochemical characteristics of the soil are given in Table 16.

Table 16. Physico-chemical characteristics of the soil used for pot culture (Experiment 2).

1. Texture	Silty loam
2. Particle size distribution	
Sand (%)	50.4
Silt (%)	38.2
Clay (%)	11.4
3. pH (1:2)	8.6
4. Conductivity (1:2) (m mhos/cm)	0.35
5. Cation Exchange Capacity (me/100 g soil)	8.6
6. Calcium carbonate (%)	1.40
7. Organic carbon (%)	0.38
8. Total nitrogen (%)	0.053
9. Available phosphorus (kg/ha P)	29.6
10. Available potassium (kg/ha K)	230.0

There were 12 treatments in all (Table 17). Each treatment was replicated thrice. Ammonium sulphate and dipotassium hydrogen phosphate were used as fertilizer for basal dressing according to Thorne (1954). The plants were sprayed at 10th week and 14th week after sowing with 2 ml of 0.78 percent aqueous sodium dihydrogen orthophosphate, 2 ml of a 2 percent aqueous urea solution or a mixture of the two in the ratio of 1:1 taking care that none of the spray solution fell on the soil in the pots. The control was sprayed with de-ionized water only.

1. <u>Sampling technique</u>

To study growth and development, samples were collected at two stages of growth 14th and 20th week after sowing, the latter synchronising with the stage when plants were ready for the market. After sampling, growth assessment was made which is mentioned below:

2. <u>Growth assessment</u>

The following growth assessments were made:

(i) Diameter of the plant
(ii) Fresh weight
(iii) Dry weight

3. <u>Leaf analysis</u>

Leaf analysis for N, P and K was carried out following the methods mentioned in the sand culture experiment.

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Table 17. Schedule of basal and spray application of nitrogen and phosphorus for pot culture (Experiment 2).

Treatment	Basal	Spray
T_1	No NPK	De-ionized water
T_2	"	N
T_3	"	P
T_4	"	N + P
T_5	Half NPK	De-ionized water
T_6	"	N
T_7	"	P
T_8	"	N + P
T_9	Full NPK	De-ionized water
T_{10}	"	N
T_{11}	"	P
T_{12}	"	N + P

According to Thorne 1954
(see page 44 thesis)

	Nil	Half	Full
$(NH_4)_2SO_4$	0	3 gm/pot	6 gm/pot
K_2HPO_4	0	1.65 gm/pot	3.3 gm/pot

II. <u>Field experiments</u>

<u>Experiment 3</u>. A field experiment to compare the effect of various doses of foliar-applied nitrogen, phosphorus and their combinations on the yield and grain quality of three hybrid varieties of maize, namely Ganga-5, Ganga-7 and Kisan, grown with half the recommended dose of basal nitrogen and phosphorus, was carried out on a silty loam soil during the 'Kharif' (summer) season of 1973. The physico-chemical characteristics of the soil, as determined by routine laboratory procedures, are given in Table 24. A basal dressing of 80 kg/ha K_2O, as muriate of potash, was applied uniformly to the entire field after it was properly prepared for the experiment. The experiment was laid out according to a factorial block design. The treatments included in this experiment are summarized in Table 25. The following rates indicate the full dose of basal and spray nitrogen and phosphorus (N and P), respectively.

<u>Basal fertilisers (commercial grade)</u>

Urea : 2.67 quintals (q)/ha containing 1.20 q N/ha,

Monocalcium superphosphate : 3.75 q /ha containing
~~2.32~~ q P_2O_5/ha.
0.6

<u>Spray chemicals (laboratory grade)</u>

Urea : 2 percent aqueous solution at the rate of 13.5 kg N/ha,

Sodium dihydrogen orthophosphate : 0.2 percent aqueous solution at the rate of 2 kg P_2O_5/ha.

Table ~~24~~ 6. Physico-chemical characteristics of surface soil of the experimental plot (Experiment 3).

1. Texture	silty loam
2. Particle size distribution	
Sand (%)	49.20
Silt (%)	37.60
Clay (%)	13.20
3. pH (1:2)	8.50
4. Conductivity (1:2) (m mhos/cm)	0.60
5. Cation exchange capacity (me/100 g soil)	7.80
6. Calcium carbonate (%)	1.52
7. Organic carbon (%)	0.57
8. Total nitrogen (%)	0.062
9. Available phosphorus (kg/ha P)	16.00
10. Available potassium (kg/ha K)	226.00

Table ~~26~~ 7. Schedule of basal and spray application of nitrogen and phosphorus for Field Experiment 3.

Treatment	Basal	Spray
T_1	No NP	De-ionized water
T_2	Half N + Half P	De-ionized water
T_3	"	1/2 N
T_4	"	1/2 P
T_5	"	1/2 N + 1/2 P
T_6	"	N
T_7	"	P
T_8	"	N + P

The treatments included in this experiment are summarized in Table 35. Thus, the design of the experiment consisted of eight fertility levels, each replicated thrice.

The size of each treated plot was 2 x 3 meters. Disease free seeds of uniform size and weight were selected and treated with 'Paradoxon', a commercial fungicide. The usual "behind the plough" method of sowing was adopted. Each plot was divided into seven uniform rows and eight seeds were sown in each row on 26th June 1973. The field received three irrigations between sowing and harvesting, 15, 40 and 75 days after sowing. Weeding was done thrice, 20, 45 and 65 days after sowing. The crop was harvested on 28th September, 1973.

Spraying was done at the time of Silking (female flowering.) Necessary precautions were taken to apply the solutions uniformly and to prevent them from falling on the soil. This was facilitated by spraying late in the evenings as the wind velocity at that time of the day was lowest. The controls were sprayed with de-ionized water only.

<u>Experiment 4</u>. The second field experiment on maize was planned in the light of the results of the earlier field trial (Experiment 3). It was conducted in a newly acquired field, the physico-chemical characteristics of whose soil are summarized in Table 36. In this experiment also basal fertilizers consisted of muriate of potash (which was applied uniformly to the entire field at the time of

Table 3~~6~~8. Physico-chemical characteristics of surface soil of the experimental plot (Experiment 4).

1. Texture	Silty loam
2. Particle size distribution	
Sand (%)	49.00
Silt (%)	38.00
Clay (%)	13.00
3. pH (1:2)	8.60
4. Conductivity (1:2) (m mhos/cm)	0.40
5. Cation Exchange Capacity (me/100 g soil)	7.82
6. Calcium carbonate (%)	1.56
7. Organic carbon (%)	0.74
8. Total nitrogen (%)	0.058
9. Available phosphorus (kg/ha P)	16.60
10. Available potassium (kg/ha K)	220.00

preparation), urea and monocalcium superphosphate. The last two were, however, applied in three combinations (full N + full P; full N + half P and half N + half P) at the time of sowing. It was also decided to increase the number of doses of phosphorus in the spray to test if fertiliser economy could be effected, while maintaining the yields at optimum level; but this necessitated the exclusion of nitrogen from the sprays to keep the number of treatments manageable.

Thus, the object of this experiment was two-fold: first, to test the effect of various doses of leaf-applied phosphorus on the yield and grain quality of maize under conditions of full soil fertility and secondly to test if any of the doses of spray phosphorus could compensate for the cut in basal fertilisation so as to save this costly input (cf. Afridi and Samiullah, 1973a - for barley).

The various treatments selected for this experiment are summarized in Table ~~37~~ 9. The experiment was laid out according to a factorial block design. It included twelve fertility levels, each replicated thrice.

The details of the preparation of the field, including plotting, the doses of full fertiliser applied as basal dressing and spray, irrigation, weeding and spraying technique have been described under Experiment 3. Seeds were sown on 30th June, 1974 and the crop, harvested on 3rd October, 1974.

Table ~~37~~ 9. Schedule of basal and spray application of nitrogen and phosphorus for Field Experiment 4.

Treatment	Basal	Spray
T_1	Full N + Full P	De-ionized water
T_2	"	1/2 P
T_3	"	P
T_4	"	2 P
T_5	Full N + Half P	De-ionized water
T_6	"	1/2 P
T_7	"	P
T_8	"	2 P
T_9	Half N + Half P	De-ionized water
T_{10}	"	1/2 P
T_{11}	"	P
T_{12}	"	2 P

Basal.

Page 46 { Full N = 1.20 g N/ha = 2.67 g/ha UREA
Full P = 0.60 g P/ha = 3.75 g/ha Superphosphate

Assessment of yield and grain quality. Unlike the pot culture experiments, attention was focussed in the two field experiments on yield and grain quality as affected by various treatments.

(a) Yield analysis

The crop was harvested after the cobs were fully ripened and dried. Yield was taken after thrashing the grains from the cobs. The yield characteristics studied are given below:

(i) Cob yield per plant
(ii) Cob yield per hectare
(iii) Grain yield per plant
(iv) Grain yield per hectare

(b) Grain analysis

Grain analysis was done to assess the carbohydrate and protein content of the grain. The grains of each sample were cleaned and dried in an oven running at 90°C. After half an hour the grains were ground to a fine powder by an electrically operated grinder. The powder was passed through a 25 mesh sieve and collected in a polythene bag. After labelling, the bags were kept in a dry place.

Before weighing the grain powder, a sufficient amount was spread out in a thin layer on a clean sheet of paper and dried over-night at 90°C in an oven. The dried samples were kept in a desiccator.

The following data for the grains were obtained by the methods described below:

(i) Percentage of soluble carbohydrates
(ii) Percentage of insoluble carbohydrates
(iii) Percentage of total carbohydrates
(iv) Percentage of soluble proteins
(v) Percentage of insoluble proteins
(vi) Percentage of total proteins

I. Carbohydrates

Soluble and insoluble carbohydrates were extracted by the method of Yih and Clark (1965). 50 mg of dry powder was weighed and transferred to a centrifuge tube carefully. 5 ml of 80 percent alcohol was added and heated gently on a water-bath for 10 minutes. After cooling, the samples were centrifuged at 4,000 rpm for 10 minutes. The supernatant liquid was taken in a 25 ml volumetric flask. The residue was retained in the centrifuge tube after being washed twice with 5 ml of 80 percent alcohol, the washings being added to the volumetric flask. The volume was made up to the mark with 80 percent alcohol. 1 ml of the above solution was taken in a 10 ml test tube and the alcohol evaporated on a water-bath. The test tube with the dry residue was taken out from the water-bath, cooled and the residue redissolved in 2 ml of double distilled water.

Soluble and insoluble carbohydrates were determined by a modified phenol-sulphuric acid method of Dubois et al. (1956). For soluble carbohydrates, 1 ml of 5 percent aqueous phenol solution was added to the test tube containing the 2 ml aqueous extract followed by the addition of 5 ml of concentrated sulphuric acid. The colour turned to yellowish orange. After waiting for half an hour, so as to cool the solution, it was transferred to a colorimetric tube and the optical density read at 490 nm on a "Spectronic 20" colorimeter. A blank was run with each sample. The soluble carbohydrate content of each sample was obtained by comparing its optical density with a calibration curve plotted by taking known dilutions of a standard solution of chemically pure glucose.

The residue retained in the centrifuge tube was used for the determination of insoluble carbohydrates. 5 ml of 1.5 N sulphuric acid was added to this residue and heated on a water-bath for about 2 hours. After allowing to cool, it was poured in a previously cooled centrifuge tube and centrifuged at 4,000 rpm for 10 minutes. The supernatant was collected in a 25 ml volumetric flask. The residue was washed twice with double distilled water and the washings added to the volumetric flask. The volume was made up to the mark with double distilled water. The insoluble carbohydrates were determined in 2 ml samples of this extract using the method described above for the estimation of soluble carbohydrates.

II. Proteins

Proteins were estimated by adopting the method of Lowry *et al.* (1951). 50 mg of dry powder was weighed and transferred to a mortar and pestle. The powder was ground with 5 ml of double distilled water and collected in a centrifuge tube. This was centrifuged at 4,000 rpm for 10 minutes. The supernatant was collected in a 25 ml volumetric flask and the residue, retained in the centrifuge tube. The following chemically pure reagents were used for the estimation of soluble and insoluble proteins:

Reagents

Reagent A: 2 percent sodium carbonate in 0.1 N sodium hydroxide in the ratio of 1:1.

Reagent B: 0.5 percent copper sulphate in 1 percent sodium tatrate in the ratio of 1:1.

Reagent C (alkaline copper sulphate solution): 50 ml of reagent A plus 1 ml of reagent B.

Reagent D (carbonate-copper sulphate solution): 50 ml of 2 percent sodium carbonate plus 1 ml of reagent B.

Reagent E (diluted folin reagent): Folin-ciocalteu reagent diluted to make it 1 N in acid.

For soluble protein, 0.5 ml of centrifuged supernatant was taken in a 10 ml test tube and 0.5 ml of double distilled water, followed by 5 ml of reagent C, was added to it. The test tube was well shaken and then allowed to stand for 10 minutes at room temperature. 0.5 ml of reagent E was added rapidly with constant stirring to develop the colour. After waiting for 30 minutes the blue coloured solution was transferred to a colorimetric tube and the optical density, read at 660 nm on a "Spectronic 20" colorimeter. A blank was run simultaneously. The protein content of each sample was obtained by comparing its optical density with a calibration curve plotted by taking known dilutions of a standard solution of ov-albumen.

Insoluble protein was estimated applying the same method (Lowry <u>et</u> <u>al</u>. 1951). To the residue in the centrifuge tube was added 5 ml of 5 percent trichloroacetic acid. The tube was shaken vigorously and allowed to stand for 30 minutes at room temperature, after which it was centrifuged for 10 minutes at 4,000 rpm and the supernatant, discarded. To the residue 5 ml of 1 N sodium hydroxide was added and mixed well. After 30 minutes, the solution was centrifuged and the supernatant was collected in a 25 ml volumetric flask. The volume was made up to the mark with double distilled water. This extract was used for the estimation of insoluble protein.

0.2 ml of the above mentioned solution was taken in a test tube (marked at 10 ml) to which was added 0.8 ml of double distilled water and 5 ml of reagent D. The solution was allowed to stand for 10 minutes and then 0.5 ml of reagent E was added and the volume made up to mark with water. After waiting for

30 minutes, the blue coloured solution was transferred to a colorimetric tube and the optical density, read at 660 nm on a "Spectronic 20" colorimeter. A blank was run with each sample. The insoluble protein content was read from the calibration curve used for soluble proteins.

CHAPTER IV

EXPERIMENTAL RESULTS

I. Pot experiments

A. Sand culture

Experiment 1. In this experiment, the effect of various doses of nitrogen, phosphorus and their combinations, applied as basal dressing and as foliar spray, on growth, yield and nutrient content of three varieties of barley (*Hordeum vulgare* L.), was studied in sand culture during the year 1971-72. The varieties tested were RS 6 (V_1), IB 226 (V_2) and K 572/10 (V_3). The data are given below and summarized in Tables ~~4~~ 10 to ~~16~~ 21.

1. Growth characteristics

Data regarding growth characteristics were recorded at two stages of growth, namely, heading and milky grain stage. These are presented in Tables ~~4~~ 10 to ~~8~~ 14. The effect of nitrogen, phosphorus and their combinations on each of the characteristics at these two stages is considered briefly in the following pages:

(i) Shoot length. At heading, the effect of different treatments on shoot length was found to be non-significant (Table ~~4~~ 10). However, the response of different varieties was found significant. Variety V_2 gave the maximum response and differed critically with the other two varieties.

Table ~~4~~ 10. Effect of different doses of basal and foliar - applied nitrogen, phosphorus and their combinations, on shoot length per plant in three varieties of barley at two stages of growth (cm).

STAGE	VARIETIES	TREATMENTS														MEAN
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
HEADING	V_1	83.70	81.60	83.30	86.80	88.40	83.50	81.40	82.70	82.40	81.20	80.30	79.20	71.70	74.40	81.47
	V_2	78.60	86.00	82.40	83.60	86.40	87.00	84.10	90.90	86.20	83.20	83.00	80.60	85.50	84.50	84.43
	V_3	71.50	75.90	82.40	74.20	73.90	79.00	77.30	76.90	74.30	80.50	70.10	80.10	72.60	74.30	75.93
	MEAN	77.93	81.16	82.70	81.53	82.90	83.17	80.93	83.50	80.97	81.63	77.80	79.97	76.60	77.73	
MILKY GRAIN	V_1	85.50	96.00	92.00	87.80	83.70	88.00	91.50	92.40	97.60	82.40	94.20	87.30	92.20	95.60	90.44
	V_2	88.70	91.40	101.60	98.50	92.20	89.20	90.00	100.40	106.50	97.40	98.50	96.20	100.20	101.10	96.56
	V_3	84.70	87.40	85.30	94.30	82.90	86.40	83.80	87.40	92.60	88.00	83.30	90.60	92.00	86.80	87.54
	MEAN	86.30	91.60	92.96	93.53	85.26	87.86	88.43	93.40	98.90	89.26	92.00	91.36	94.80	94.50	

					HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment	(T)	at	5%	=	N.S.	6.11*
C.D. for variety	(V)	at	5%	=	2.7590*	2.8265*

* Significant

N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

	T_9	T_{13}	T_{14}	T_4	T_8	T_3	T_{11}	T_2	T_{12}	T_{10}	T_7	T_6	T_1	T_5
MILKY GRAIN STAGE	98.90	94.80	94.50	93.53	93.40	92.96	92.00	91.60	91.36	89.26	88.43	87.86	86.30	85.26

At milky grain stage, the effect of different treatments on shoot length was found significant. Treatment T_9 gave the maximum value but its effect was statistically equal to that of T_{13}, T_{14}, T_4, T_8 and T_3. Treatments T_{12}, T_{10}, T_7, T_6, T_1 and T_5 had equally poor effect with T_5 giving the lowest value. At this stage also varietal differences were significant. Variety V_2 gave the maximum value and differed critically with the other two varieties.

(ii) Tiller number. At heading, the effect of different treatments on the production of tillers was found significant (Table 11). Treatment T_6 produced the maximum number of tillers but statistically it had equal effect with the treatments T_4, T_7, T_5, T_1 and T_3. Differences among varieties at this stage were also significant. Variety V_3 produced the maximum number of tillers followed by V_1 and V_2.

At milky grain stage, the effect of different treatments on the production of tillers was found significant. Treatment T_1 produced the maximum number of tillers. However, the effect was equal to that of treatments T_3, T_5 and T_2. Treatment T_9 produced the minimum number of tillers but T_{12}, T_{10}, T_{14}, T_8, T_{13} and T_{11} also had equally poor effect. The differences among varieties at this stage were found to be significant. Variety V_3 produced the maximum number of tillers. Its performance differed critically with that of V_2 and V_1 which showed equal effect.

Table ~~8~~ 11. Effect of different doses of basal and foliar - applied nitrogen, phosphorus and their combinations, on tiller number per plant in three varieties of barley at two stages of growth.

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	6.20	6.40	7.00	8.00	7.60	7.60	9.00	5.60	7.40	4.40	5.40	5.20	6.00	5.80	6.54
	V_2	6.80	6.80	8.00	7.20	7.20	9.00	7.40	5.40	4.80	5.40	4.40	4.60	4.40	4.00	6.10
	V_3	10.20	7.40	8.20	9.20	9.00	8.80	7.60	6.60	6.80	7.20	6.80	7.00	5.80	8.20	7.77
	MEAN	7.73	6.86	7.73	8.13	7.93	8.46	8.00	5.86	6.33	5.66	5.53	5.60	5.40	6.00	
MILKY GRAIN	V_1	10.40	9.40	10.40	8.40	11.60	8.60	7.00	5.40	5.00	6.80	5.40	5.20	6.40	5.20	7.52
	V_2	12.60	11.00	11.80	9.60	11.40	12.40	9.20	5.60	4.80	4.80	4.60	6.40	4.60	5.80	8.19
	V_3	16.00	13.60	13.00	12.60	11.80	10.00	15.00	9.60	7.20	9.60	9.60	10.20	9.00	9.80	11.22
	MEAN	13.00	11.33	11.73	10.20	11.60	10.33	10.40	6.86	5.66	7.06	6.53	7.26	6.66	6.93	

		HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment	(T) at 5% =	1.51*	2.24*
C.D. for variety	(V) at 5% =	0.6999*	1.0363*

* Significant

BAR DIAGRAM FOR TREATMENTS

HEADING STAGE	T_6	T_4	T_7	T_5	T_1	T_3	T_2	T_9	T_{14}	T_8	T_{10}	T_{12}	T_{11}	T_{13}
	8.46	8.13	8.00	7.93	7.73	7.73	6.86	6.33	6.00	5.86	5.66	5.60	5.53	5.40

MILKY GRAIN STAGE	T_1	T_3	T_5	T_2	T_7	T_6	T_4	T_{12}	T_{10}	T_{14}	T_8	T_{13}	T_{11}	T_9
	13.00	11.73	11.60	11.33	10.40	10.33	10.20	7.26	7.06	6.93	6.86	6.66	6.53	5.66

(iii) Leaf number. At heading stage, the effect of different treatments on leaf number was found to be significant (Table ~~6~~ 12). Treatment T_6 gave the maximum leaf number showing equal effect with T_5, T_7, T_4, T_3 and T_2 and treatment T_{13}, the minimum. However, statistically speaking, treatment T_{13} showed equal effect with the treatments T_2, T_1, T_8, T_{14}, T_9, T_{11}, T_{10} and T_{12}. The response of different varieties was also found to be significant. Variety V_3 produced the highest leaf number while V_2 produced the lowest, all three varieties differing critically with each other as regards leaf number at this stage.

At milky grain stage, different treatments affected leaf production significantly. Treatment T_5 produced the maximum number of leaves, the effect being equal to that of T_6, T_1, T_2, T_3, T_7 and T_4. Treatment T_{11} produced the minimum number of leaves together with T_{14}, T_{10}, T_{12}, T_{13} and T_9. Among the varieties, V_3 produced significantly higher number of leaves than V_2 and V_1, the latter two showing equal effect.

(iv) Fresh weight. At heading, the effect of different treatments on the fresh weight of plants was found significant (Table ~~7~~ 13). Treatment T_6 (with T_5, T_7, T_2, T_4, T_3 and T_1) gave the highest value and T_{13}, as also T_9, T_{10}, T_{11}, T_{14} and T_{12}, the lowest. The effect of different varieties at this stage was also significant. Variety V_2 gave the maximum value but its performance was equal to that of V_1. The performance of V_3

Table ~~6~~ 12. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on leaf number per plant in three varieties of barley at two stages of growth.

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	28.20	30.40	34.60	31.60	34.80	33.80	38.80	31.00	32.40	22.40	25.00	25.00	28.40	25.20	30.12
	V_2	29.60	30.20	31.80	33.60	30.80	36.20	32.60	26.20	22.40	25.00	23.20	22.20	22.00	20.80	27.62
	V_3	30.20	32.80	34.20	38.00	39.60	35.40	32.00	29.60	29.40	30.00	32.00	30.20	26.40	39.80	32.83
	MEAN	29.33	31.13	33.53	34.40	35.06	35.13	34.46	28.93	28.06	25.80	26.73	25.38	25.60	28.60	
MILKY GRAIN	V_1	44.40	42.40	42.80	42.80	50.40	43.80	32.60	28.20	25.60	30.00	26.60	25.80	27.60	27.80	34.99
	V_2	46.60	48.60	45.80	39.40	46.60	57.60	45.60	26.60	24.60	24.20	21.40	26.40	23.20	28.60	36.09
	V_3	58.60	58.00	56.60	53.00	57.80	50.60	64.20	55.80	32.00	37.40	33.20	38.20	33.40	36.80	47.53
	MEAN	49.86	49.66	48.40	45.06	51.60	50.66	47.46	36.86	27.40	30.53	26.73	30.13	28.06	31.06	

		HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment	(T) at 5% =	5.70*	8.61*
C.D. for variety	(V) at 5% =	2.6380*	3.9839*

* Significant

BAR DIAGRAM FOR TREATMENTS

	T_6	T_5	T_7	T_4	T_3	T_2	T_1	T_8	T_{14}	T_9	T_{11}	T_{10}	T_{12}	T_{13}
HEADING STAGE	35.13	35.06	34.46	34.40	33.53	31.13	29.33	28.93	28.60	28.06	26.73	25.80	25.80	25.60
	T_5	T_6	T_1	T_2	T_3	T_7	T_4	T_8	T_{14}	T_{10}	T_{12}	T_{13}	T_9	T_{11}
MILKY GRAIN STAGE	51.60	50.66	49.86	49.66	48.40	47.46	45.06	38.86	31.06	30.53	30.13	28.06	27.40	26.73

Table ~~7~~ 13. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on fresh weight of five plants in three varieties of barley at two stages of growth (g).

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	198.0	213.0	200.5	196.5	207.7	209.0	228;0	168.0	169.5	136.5	130.5	138.0	134.0	112.0	174.4
	V_2	196.5	202.0	199.5	206.0	223.5	243.0	225.0	175.5	146.5	154.0	152.5	137.0	129.0	146.5	181.2
	V_3	175.5	185.0	190.5	193.0	196.5	194.0	162.5	127.0	130.0	152.5	150.5	138.5	114.5	166.0	162.6
	MEAN	190.0	200.0	196.8	198.5	209.2	215.3	205.2	156.8	148.7	147.7	144.5	137.8	125.8	141.5	
MILKY GRAIN	V_1	259.6	249.2	253.1	289.8	263.0	271.0	273.0	194.9	185.3	179.1	183.0	184.7	215.4	194.8	228.3
	V_2	264.1	291.6	308.5	296.9	279.0	334.0	289.6	204.3	204.0	194.7	177.2	183.4	205.7	208.0	245.8
	V_3	246.6	239.4	210.3	247.0	184.9	216.0	257.0	167.0	183.8	190.7	169.2	165.8	176.0	163.6	201.2
	MEAN	256.8	260.1	257.3	277.9	242.3	273.7	273.2	188.8	191.0	188.2	176.5	178.0	199.0	188.8	

	HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment (T) at 5% =	27.71*	32.59*
C.D. for variety (V) at 5% =	12.8266*	15.088*

* Significant

BAR DIAGRAM FOR TREATMENTS

HEADING STAGE	T_6	T_5	T_7	T_2	T_4	T_3	T_1	T_8	T_9	T_{10}	T_{11}	T_{14}	T_{12}	T_{13}
	215.3	209.2	205.2	200.0	198.5	198.8	190.0	156.8	148.7	147.7	144.5	141.5	137.8	125.8

MILKY GRAIN STAGE	T_4	T_6	T_7	T_2	T_3	T_1	T_5	T_{13}	T_9	T_8	T_{14}	T_{10}	T_{12}	T_{11}
	277.9	273.7	273.2	260.1	257.3	256.8	242.3	199.0	191.0	188.8	188.8	188.2	178.0	176.5

was poorest but equal to that of V_1.

At milky grain stage, the effect of different treatments on the fresh weight was found significant. Treatment T_4 gave the maximum value and T_{11}, the minimum. However, T_6, T_7, T_2, T_3 and T_1 performed as well as T_4 whereas T_{13}, T_9, T_8, T_{14}, T_{10}, and T_{12} gave as poor a performance as T_{11}. The effect of different varieties on fresh weight was found to be significant. Variety V_2 showed the maximum response and differed critically with the other two varieties which performed in the order $V_1 > V_3$.

(v) Dry weight. At heading, the effect of different treatments was found significant (Table ~~8~~ 14). Treatment T_7 which gave the maximum dry weight showed equal effect to that of T_6, T_5, T_3, T_1 and T_2. The minimum dry matter was produced by treatment T_{13} but the effect was shared by T_{11}, T_{10}, T_9, T_{12}, T_{14} and T_8. Varietal difference for this character at heading were non-significant.

At milky grain stage, the effect of different treatments on dry weight was found to be significant. Treatment T_2 gave the highest value together with T_1, T_7, T_5 and T_6. Treatment T_{11} (as also T_{10}, T_{12}, T_8, T_9 and T_{14}) produced the least dry matter. The difference in the performance of the three varieties was also found significant. Variety V_2 gave the maximum dry weight and differed critically with the other two varieties, which had equal effect.

Table 8. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on dry weight of five plants in three varieties of barley at two stages of growth (g).

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	26.00	23.10	26.00	22.50	25.30	23.00	27.50	10.40	20.50	16.70	17.60	17.00	17.20	12.50	20.40
	V_2	22.40	24.70	23.10	21.00	23.30	27.20	24.40	23.00	18.50	20.00	20.00	16.40	16.50	16.80	21.20
	V_3	25.20	23.40	24.80	26.00	26.40	25.40	24.40	17.20	17.40	20.30	21.00	19.70	14.50	22.20	22.00
	MEAN	24.50	23.70	24.60	23.20	25.00	25.20	25.40	16.90	18.80	19.00	19.50	17.70	16.10	17.20	
MILKY GRAIN	V_1	49.20	52.20	45.50	45.50	52.00	49.00	48.50	44.20	43.00	44.50	35.20	44.70	47.70	42.00	45.90
	V_2	54.00	55.00	51.00	50.00	57.00	57.40	50.50	43.50	46.50	46.20	42.50	42.00	45.50	45.60	49.10
	V_3	52.70	52.00	44.00	45.30	45.20	46.00	55.50	42.50	40.00	44.20	43.50	44.00	44.50	36.00	45.40
	MEAN	52.00	53.10	47.00	46.90	51.40	50.80	51.50	43.40	43.20	45.00	40.40	43.60	45.90	41.00	

	HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment (T) at 5% =	4.45*	5.09*
C.D. for variety (V) at 5% =	N.S.	2.3553*

* Significant
N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

	T_7	T_6	T_5	T_3	T_1	T_2	T_4	T_{11}	T_{10}	T_9	T_{12}	T_{14}	T_8	T_{13}
HEADING STAGE	25.40	25.20	25.00	24.60	24.50	23.70	23.20	19.50	19.00	18.80	17.70	17.20	16.90	16.10
	T_2	T_1	T_7	T_5	T_6	T_3	T_4	T_{13}	T_{10}	T_{12}	T_8	T_9	T_{14}	T_{11}
MILKY GRAIN STAGE	53.10	52.00	51.50	51.40	50.80	47.00	46.90	45.90	45.00	43.60	43.40	43.20	41.00	40.40

2. Yield characteristics

Data regarding yield characteristics were recorded at harvest and are presented in Tables 9 to 12. A brief account of the salient features of each of the characteristic studied is given below:

(i) Ear number per plant. The effect of different treatments on the production of ears was found significant (Table ~~9~~ 15). Treatment T_4 produced maximum ears and differed critically with all other treatments except T_6. Treatment T_8 produced the minimum number of ears per plant. The effect of treatments T_{12}, T_1, and T_{11} was equally poor. The varieties, however, showed no significant differences in their performance regarding ear production.

(ii) Ear weight per plant. The effect of different treatments on ear weight per plant was found to be significant (Table 10 16). Treatment T_6 gave the maximum value and differed critically with all other treatments. Treatment T_4 gave the value next to T_6 while T_1 gave the minimum value. The effect of different varieties on ear weight per plant was found significant. Variety V_1 gave the highest value and V_2, the lowest.

(iii) Grain weight per plant. The response of different treatments on the grain weight per plant was found significant (Table ~~11~~ 17). Treatment T_6 gave the highest value which differed critically with all other treatments. Treatment T_4 gave the

Table ~~9~~ 15. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on ear number per plant in three varieties of barley.

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
V_1	4.6	5.2	6.4	7.0	5.4	7.2	5.8	3.6	4.2	4.6	3.8	4.4	4.6	5.4	5.16
V_2	3.8	5.0	5.9	7.4	5.0	6.8	6.1	4.0	4.5	4.9	3.9	4.0	4.5	5.0	5.06
V_3	3.4	4.9	5.2	7.3	5.1	6.6	6.0	3.9	4.2	4.6	4.0	3.8	4.7	4.9	4.90
MEAN	3.93	4.03	5.83	7.23	5.17	6.87	5.97	3.83	4.30	4.70	3.90	4.07	4.60	5.10	

C.D. for treatment (T) at 5% = 0.4678*
C.D. for variety (V) at 5% = N.S.

* Significant
N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

T_4	T_6	T_7	T_3	T_5	T_{14}	T_2	T_{10}	T_{13}	T_9	T_{12}	T_1	T_{11}	T_8
7.23	6.87	5.97	5.83	5.17	5.10	5.03	4.70	4.60	4.30	4.07	3.93	3.90	3.83

Table ~~10~~ 16. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on ear weight per plant in three varieties of barley (g).

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
V_1	5.46	5.74	6.08	12.10	10.32	17.56	11.92	6.94	9.82	11.38	6.98	7.90	7.68	9.62	9.25
V_2	5.00	5.64	6.00	11.92	9.88	16.76	11.00	6.62	8.98	11.02	6.72	7.65	7.20	9.00	8.81
V_3	5.40	5.62	6.04	12.00	10.12	16.81	10.79	6.08	9.00	11.00	6.68	7.87	8.00	9.42	8.92
MEAN	5.22	5.67	6.04	12.01	10.11	17.04	11.24	6.55	9.27	11.13	6.79	7.81	7.63	9.35	

C.D. for treatment (T) at 5% = 0.3972*
C.D. for variety (V) at 5% = 0.18388*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_4	T_7	T_{10}	T_5	T_{14}	T_9	T_{12}	T_{13}	T_{11}	T_8	T_3	T_2	T_1
17.04	12.01	11.24	11.13	10.11	9.35	9.27	7.81	7.63	6.79	6.55	6.04	5.67	5.22

Table 17 ~~11~~. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on grain weight per plant in three varieties of barley (g).

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
V_1	4.36	4.70	5.10	11.98	9.20	16.50	10.90	5.45	8.80	10.28	5.90	6.87	6.62	8.81	8.25
V_2	4.06	4.60	5.07	10.88	8.90	15.69	9.98	5.50	7.87	10.01	5.68	6.60	6.10	8.04	7.78
V_3	4.45	4.80	5.00	11.06	9.10	15.80	9.74	5.00	8.04	10.01	5.62	6.81	7.04	8.39	7.92
MEAN	4.29	4.70	5.06	11.31	9.07	16.00	10.21	5.32	8.24	10.10	5.73	6.76	6.59	8.41	

C.D. for treatment (T) at 5% = 0.4539*
C.D. for variety (V) at 5% = 0.21013*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_4	T_7	T_{10}	T_5	T_{14}	T_9	T_{12}	T_{13}	T_{11}	T_8	T_3	T_2	T_1
16.00	11.31	10.21	10.10	9.07	8.41	8.24	6.76	6.59	5.73	5.32	5.06	4.70	4.29

value next to T_6 while T_1 gave the minimum grain weight per plant, the poor effect being shared by T_2.

The effect of different varieties on grain weight per plant was found to be significant. Variety V_1 gave the maximum value and V_2, the minimum.

(iv) Straw weight per plant. The effect of different treatments on straw weight per plant was found significant (Table ~~12~~ 18). Treatment T_6 produced maximum straw per plant and differed critically with all other treatments. Treatment T_{11} produced the minimum response. The effect of different varieties on straw weight per plant was found non-significant.

3. Nutrient content

Results pertaining to the NPK content of leaves were recorded at two stages of growth, namely, heading and milky grain stage. The data are summarized in Tables ~~13~~ 19 to ~~15~~ 21 and are briefly stated below:

(i) Nitrogen. At heading, the effect of different treatments on the percentage of nitrogen was found significant (Table ~~13~~ 19). Treatment T_3 (as also T_1, T_4, T_7, T_2, T_5, T_{12} and T_8) gave the maximum percentage of nitrogen. Treatment T_{13} gave the minimum percentage of nitrogen, the effect being equal to that of T_{12}, T_8, T_9, T_6, T_{14}, T_{11} and T_{10}. Varietal differences were also found to be significant. Variety V_2 gave the maximum value and

Table ~~12~~ 18. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on straw weight per plant in three varieties of barley (g).

VARIETIES	TREATMENTS														MEAN
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
V_1	9.28	7.90	9.40	9.30	10.30	13.50	9.86	7.44	7.20	8.06	6.30	7.20	7.80	9.20	8.76
V_2	8.96	8.12	9.64	9.14	10.16	12.98	9.50	7.36	7.04	8.16	6.40	7.42	7.54	8.54	8.64
V_3	9.60	8.56	10.02	9.56	10.52	12.14	9.18	7.64	7.56	8.48	6.14	7.34	7.84	8.12	8.76
MEAN	9.28	8.19	9.69	9.33	10.33	12.87	9.51	7.48	7.27	8.23	6.28	7.32	7.73	8.62	

C.D. for treatment (T) at 5% = 0.551*
C.D. for variety (V) at 5% = N.S.

* Significant
N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_5	T_3	T_7	T_4	T_1	T_{14}	T_{10}	T_2	T_{13}	T_8	T_{12}	T_9	T_{11}
12.87	10.33	9.69	9.51	9.33	9.28	8.62	8.23	8.19	7.73	7.48	7.32	7.27	6.28

Table ~~18~~ 19. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of nitrogen in leaves of three varieties of barley at two stages of growth.

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	3.05	3.08	4.26	3.08	3.38	3.51	3.66	2.40	2.69	2.55	2.48	2.80	2.95	2.80	3.064
	V_2	3.89	3.96	3.89	4.40	3.23	3.58	3.96	4.10	3.38	2.55	2.90	2.76	1.44	2.69	3.338
	V_3	3.58	3.30	3.38	2.95	3.16	1.32	2.81	2.40	2.62	2.76	2.55	3.38	1.75	2.55	2.751
	MEAN	3.51	3.45	3.85	3.48	3.26	2.80	3.48	2.97	2.90	2.62	2.64	2.98	2.05	2.68	
MILKY GRAIN	V_1	2.43	2.69	2.80	2.81	2.55	2.95	3.38	2.55	2.55	2.40	2.10	1.86	2.55	2.90	2.609
	V_2	2.80	2.95	3.08	2.24	2.81	2.95	2.62	2.95	2.95	2.03	3.02	2.55	2.55	2.79	2.700
	V_3	3.08	2.95	3.30	3.02	3.08	3.16	3.52	2.24	2.76	2.40	2.29	2.55	2.06	2.40	2.770
	MEAN	2.77	2.86	3.06	2.69	2.81	3.02	3.17	2.58	2.75	2.28	2.47	2.32	2.39	2.53	

	HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment (T) at 5% =	0.935*	0.545*
C.D. for variety (V) at 5% =	0.43268*	N.S.

* Significant
N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

HEADING STAGE	T_3	T_1	T_4	T_7	T_2	T_5	T_{12}	T_8	T_9	T_6	T_{14}	T_{11}	T_{10}	T_{13}
	3.84	3.51	3.48	3.48	3.45	3.26	2.98	2.97	2.90	2.80	2.68	2.64	2.62	2.05

MILKY GRAIN STAGE	T_7	T_3	T_6	T_2	T_5	T_1	T_9	T_4	T_8	T_{14}	T_{11}	T_{13}	T_{12}	T_{10}
	3.17	3.06	3.02	2.86	2.81	2.77	2.75	2.69	2.58	2.53	2.47	2.39	2.32	2.28

was followed by V_1 and V_3.

At milky grain stage, the effect of different treatments on the percentage of leaf nitrogen was found significant. Treatment T_7 gave the highest percentage of nitrogen together with T_3, T_6, T_2, T_5, T_1, T_9 and T_4. The minimum value was found in T_{10} as also T_5, T_1, T_9, T_4, T_8, T_{14}, T_{11}, T_{13} and T_{12}. The effect of different varieties on the percentage of leaf nitrogen at this stage was found non-significant.

(ii) <u>Phosphorus</u>. At heading, the effect of different treatments on the percentage of phosphorus was found significant (Table ~~14~~ 20). Treatment T_{10} gave the highest percentage of phosphorus, T_{11}, T_{12}, T_9, T_{14} and T_5 producing equal effect. Lowest value was given by treatment T_1 with T_3 and T_7 giving equally poor effect. Varietal differences were also found significant. Variety V_1 gave the maximum percentage of phosphorus and variety V_3, the minimum.

The effect of different treatments on the percentage of phosphorus at the milky grain stage was found significant. Treatment T_6 gave the highest value, the effect being shared by T_5, T_3, T_1, T_2 and T_7. The performance of different varieties regarding the percentage of leaf phosphorus at this stage was non-significant.

Table ~~14~~ 20. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of phosphorus in leaves of three varieties of barley at two stages of growth.

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	0.385	0.448	0.440	0.440	0.480	0.440	0.424	0.424	0.508	0.524	0.524	0.472	0.472	0.440	0.458
	V_2	0.344	0.360	0.368	0.456	0.464	0.384	0.424	0.456	0.440	0.480	0.472	0.484	0.456	0.496	0.434
	V_3	0.360	0.424	0.412	0.440	0.404	0.416	0.360	0.448	0.480	0.480	0.448	0.484	0.384	0.448	0.427
	MEAN	0.363	0.411	0.407	0.445	0.449	0.413	0.403	0.443	0.476	0.495	0.481	0.480	0.437	0.461	
MILKY GRAIN	V_1	0.336	0.352	0.360	0.280	0.384	0.336	0.368	0.292	0.292	0.248	0.232	0.288	0.316	0.312	0.314
	V_2	0.384	0.352	0.336	0.312	0.384	0.384	0.264	0.306	0.264	0.272	0.256	0.260	0.264	0.260	0.307
	V_3	0.312	0.326	0.336	0.326	0.288	0.380	0.316	0.288	0.316	0.336	0.240	0.260	0.224	0.290	0.309
	MEAN	0.344	0.343	0.344	0.306	0.352	0.367	0.316	0.295	0.291	0.285	0.243	0.269	0.268	0.287	

		HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment (T) at 5%	=	0.04747*	0.05568*
C.D. for variety (V) at 5%	=	0.02197*	N.S.

* Significant
N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

HEADING STAGE	T_{10}	T_{11}	T_{12}	T_9	T_{14}	T_5	T_4	T_8	T_{13}	T_6	T_2	T_3	T_7	T_1
	0.495	0.481	0.480	0.476	0.461	0.449	0.445	0.443	0.437	0.413	0.411	0.407	0.403	0.363

MILKY GRAIN STAGE	T_6	T_5	T_3	T_1	T_2	T_7	T_4	T_8	T_9	T_{14}	T_{10}	T_{12}	T_{13}	T_{11}
	0.367	0.352	0.344	0.344	0.343	0.316	0.306	0.295	0.291	0.287	0.285	0.269	0.268	0.243

(iii) Potassium. At heading, the effect of different treatments on the percentage of leaf potassium was found non-significant (Table ~~16~~ 21). However, the varietal differences were found significant. Variety V_1 gave the maximum response and V_2, the minimum.

The effect of different treatments on the percentage of potassium in the leaves at milky grain stage was found significant. Treatment T_3 gave the highest percentage of potassium which differed critically with all other treatments, except T_5 and T_6. The performance of the different varieties regarding this nutrient was, however, found non-significant.

B. Soil culture

Experiment 2. In this experiment the effect of various doses of nitrogen and phosphorus applied to soil with and without spray of one or the other or both of these nutrients on growth, yield and NPK content of lettuce (*Lactuca sativa* L.) variety Suttons Golden Ball was studied in pot culture. The data are summarised below (Table ~~18~~ 22 to ~~23~~ 27).

1. Growth and yield assessment

It may be recalled that growth was judged in this experiment by the average diameter and yield by the average fresh weight of the plants at various stages of growth. In

Table ~~15~~ 21. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of potassium in leaves of three varieties of barley at two stages of growth.

STAGE	VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	MEAN
HEADING	V_1	1.80	2.60	2.20	1.90	3.30	2.50	2.20	2.90	3.10	3.10	2.60	2.20	2.60	2.70	2.55
	V_2	1.80	2.00	1.70	1.40	1.60	2.30	1.50	2.00	1.70	2.00	2.30	1.90	2.00	2.20	1.88
	V_3	1.90	2.30	2.10	1.90	2.00	2.10	1.80	2.80	2.70	2.20	2.40	2.70	1.70	2.30	2.20
	MEAN	1.87	2.30	2.00	1.73	2.30	2.30	1.83	2.57	2.50	2.43	2.43	2.27	2.10	2.40	
MILKY GRAIN	V_1	1.60	1.40	1.30	1.10	1.40	1.70	1.30	1.30	1.30	0.90	1.00	1.30	1.20	1.30	1.29
	V_2	1.40	1.30	2.00	1.40	1.60	1.50	1.30	1.10	1.00	1.20	1.30	1.00	1.00	1.30	1.31
	V_3	1.30	1.50	2.10	1.40	1.40	1.20	1.40	0.90	1.10	1.00	0.80	0.90	0.80	1.40	1.23
	MEAN	1.43	1.40	1.80	1.30	1.47	1.47	1.33	1.10	1.13	1.03	1.03	1.07	1.00	1.33	

	HEADING STAGE	MILKY GRAIN STAGE
C.D. for treatment (T) at 5% =	N.S.	0.3419*
C.D. for variety (V) at 5% =	0.538*	N.S.

* Significant
N.S. Non-significant

BAR DIAGRAM FOR TREATMENTS

	T_3	T_5	T_6	T_1	T_2	T_7	T_{14}	T_4	T_9	T_8	T_{12}	T_{10}	T_{11}	T_{13}
MILKY GRAIN STAGE	1.80	1.47	1.47	1.43	1.40	1.33	1.33	1.30	1.13	1.10	1.07	1.03	1.03	1.00

addition, dry weight was obtained to assess dry matter production. The treatments were found to affect all these characteristics significantly (Tables ~~18~~ 22 to ~~20~~ 24). Further, plants in one batch were harvested 14 weeks, and in two other batches 20 weeks, after sowing. The first batch was sprayed once 10 weeks after sowing and the other two batches twice i.e. 10 and 14 weeks after sowing.

(i) Diameter. In plants sprayed at 10th week and harvested at 14th week, the effect of treatments on the diameter of the plant was found significant. Treatment T_{10} gave the maximum value and differed critically with all other treatments. Treatment T_{12} showed the minimum response but equalled that of the control, T_1 and of T_8.

In the second batch of plants sprayed at 10th week and harvested at 20th week, the effect of treatments on the diameter was found significant. Treatment T_{10} showed the maximum response but gave statistically equal value with the treatments T_{11}, T_6, T_2, T_4, T_9 and T_8. Treatment T_1 showed the minimum value which was equal to that for T_{12} and T_3. In the third batch of plants which were sprayed at 14th week and harvested at 20th week, the effect of different treatments on the diameter was found significant. Treatment T_8 gave the maximum value and differed critically with all other treatments, except T_6, T_{11} and T_9.

Table ~~18~~ 22. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on diameter per plant in lettuce at three batches of growth (cm).

BATCHES	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	11	12
I	23.83	28.33	26.67	28.67	25.67	32.17	30.00	23.00	29.00	34.83	29.33	22.33
II	24.33	29.00	26.57	29.00	24.93	29.97	27.33	28.67	28.83	31.27	30.50	26.67
III	24.33	23.00	26.33	22.00	24.93	31.00	22.00	31.00	28.83	24.47	30.50	22.00

	BATCHES		
	I	II	III
C.D. for treatment (T) at 5% =	2.493*	2.615*	3.103*

* Significant

BAR DIAGRAM FOR TREATMENTS

	T_{10}	T_6	T_7	T_{11}	T_9	T_4	T_2	T_3	T_5	T_1	T_8	T_{12}
I BATCH	34.83	32.17	30.00	29.33	29.00	28.67	28.33	26.67	25.67	23.83	23.00	22.33
	T_{10}	T_{11}	T_6	T_2	T_4	T_9	T_8	T_7	T_{12}	T_3	T_5	T_1
II BATCH	31.27	30.50	29.97	29.00	29.00	28.83	28.67	27.33	26.67	26.57	24.93	24.33
	T_8	T_6	T_{11}	T_9	T_3	T_5	T_{10}	T_1	T_2	T_7	T_4	T_{12}
III BATCH	31.33	31.00	30.50	28.83	26.33	24.93	24.47	24.33	23.00	22.67	22.33	22.00

(ii) Fresh weight. In the first batch of plants which were sprayed at 10th week and harvested at 14th week, the effect of treatments on the fresh weight of the plant was found significant. Treatment T_{10} gave the maximum response which differed critically with that of all other treatments. Treatments T_6 gave the value next to treatment T_{10}. Treatment T_{12} showed the minimum response which was equal to that of the control, T_1.

In the second batch of plants, sprayed at 10th week and harvested at 20th week, the effect of treatments on the fresh weight was found significant. Treatment T_{10} gave the maximum value and differed critically with all other treatments in this respect. Treatment T_{12} gave the value next to treatment T_{10} and treatment T_1 showed the minimum response which also differed critically from that of the remaining treatments.

In the third batch of plants, sprayed at 14th week and harvested at 20th week, the effect of different treatments on the fresh weight was found significant. Treatment T_6 gave the maximum response and differed critically with all other treatments. Treatment T_9 gave the value next to that in treatment T_6 but showed equal effect to that of T_5. Treatment T_4 showed the minimum response which was equal to that of treatment T_{12}.

(iii) Dry weight. In plants sprayed at 10th week and harvested at 14th week, the effect of treatments on the dry weight of the

Table ~~19~~ 23. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on fresh weight per plant in lettuce at three batches of growth (g).

BATCHES	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	11	12
I	53.67	67.33	60.10	72.17	97.17	128.00	156.00	62.00	102.17	156.00	63.50	50.17
II	58.83	98.63	81.57	98.00	70.50	109.50	91.50	97.63	73.17	137.83	98.70	126.83
III	58.83	59.00	57.80	39.23	70.50	81.90	49.73	60.10	73.17	64.43	63.50	42.90

	BATCHES		
	I	II	III
C.D. for treatment (T) at 5% =	4.300*	4.513*	4.040*

* Significant

BAR DIAGRAM FOR TREATMENTS

	T_{10}	T_6	T_9	T_5	T_7	T_4	T_2	T_{11}	T_8	T_3	T_1	T_{12}
I BATCH	156.00	128.00	102.17	97.17	94.67	72.17	67.33	63.50	62.00	60.10	53.67	50.17
	T_{10}	T_{12}	T_6	T_{11}	T_2	T_4	T_8	T_7	T_3	T_9	T_5	T_1
II BATCH	137.83	126.83	109.50	98.70	98.63	98.00	97.63	91.50	81.57	73.17	70.50	58.83
	T_6	T_9	T_5	T_{10}	T_{11}	T_8	T_2	T_1	T_3	T_7	T_{12}	T_4
III BATCH	81.90	73.17	70.50	64.43	63.50	60.10	59.00	58.83	57.80	49.73	42.90	39.23

plants was found significant. Treatment T_{10} gave the maximum value and differed critically with all other treatments. Treatment T_6 gave the value next to T_{10} and it also differed critically with the rest of the treatments. Treatment T_{12} showed the minimum response which was equal to that of treatment T_1 and T_3.

In the second batch of plants, sprayed at 10th week and harvested at 20th week, the response of treatments on the dry weight of the plants was found significant. Treatment T_{10} gave the maximum response and differed critically with all other treatments, except T_{12}. The minimum value was recorded in treatment T_1 but its effect equalled that of T_5 and T_3.

In the third batch of plants which were sprayed at 14th week and harvested at 20th week, the effect of treatment on the dry weight of the plants was found significant. Treatment T_9 gave the maximum value and differed critically with all other treatments except T_5 and T_6, while T_4 gave the minimum value which was equal to that of treatment T_{12}.

2. <u>Nutrient content</u>

The NPK content of leaves was also determined at the same three stages of growth.

The data are summarised in Tables ~~21~~ 25 to ~~23~~ 27 and are briefly described below:

Table ~~20~~ 24. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on dry weight per plant in lettuce at three batches of growth (g).

BATCHES	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	11	12
I	5.33	6.23	5.33	6.97	8.03	12.23	9.10	6.17	9.33	14.70	6.07	4.57
II	7.43	9.93	8.47	10.07	8.77	12.37	11.50	11.40	9.33	15.30	10.93	14.37
III	7.43	5.43	6.03	4.33	8.77	8.53	5.30	6.20	9.33	6.37	6.83	5.23

	BATCHES		
	I	II	III
C.D. for treatment (T) at 5% =	1.118*	1.544*	0.954*

* Significant

BAR DIAGRAM FOR TREATMENTS

	T_{10}	T_6	T_9	T_7	T_5	T_4	T_2	T_8	T_{11}	T_3	T_1	T_{12}
I BATCH	14.70	12.23	9.33	9.10	8.03	6.97	6.23	6.17	6.07	5.33	5.33	4.57

	T_{10}	T_{12}	T_6	T_7	T_8	T_{11}	T_4	T_2	T_9	T_5	T_3	T_1
II BATCH	15.30	14.37	12.37	11.50	11.40	10.93	10.07	9.93	9.33	8.77	8.47	7.43

	T_9	T_5	T_6	T_1	T_{11}	T_{10}	T_8	T_3	T_2	T_7	T_{12}	T_4
III BATCH	9.33	8.77	8.53	7.43	6.83	6.37	6.20	6.03	5.43	5.30	5.23	4.33

(i) Nitrogen. The effect of treatments on the percentage of nitrogen was found significant in the first batch of plants. Treatment T_{12} recorded the highest percentage of nitrogen and differed critically with all other treatments. Treatment T_{10} gave the next lower value. The lowest value was obtained with T_5 which equalled T_7, T_1, T_9 and T_4 in this respect.

In the second batch of plants, the effect of treatments on the percentage of nitrogen was found significant. Treatment T_7 showed the maximum value and differed critically with all other treatments except T_6. T_1 gave the lowest percentage of nitrogen in this batch, the effect being equalled by T_2.

In the third batch of plants, the effect of treatments on the percentage of nitrogen was found significant. Treatment T_{12} gave the highest percentage of nitrogen and differed critically with all other treatments except T_6. The lowest value was recorded with T_1, treatments T_3 and T_2 producing equal effect with T_1.

(ii) Phosphorus. In the first batch of plants, the effect of treatments on the percentage of leaf phosphorus was found significant. Treatment T_{11} gave the maximum value and differed critically with all other treatments except T_8. Treatment T_1 gave the minimum percentage of phosphorus in this batch, T_2 also giving equally poor effect.

Table ~~21~~ 25. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of nitrogen in leaves per plant of lettuce at three batches of growth.

BATCHES	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	11	12
I	1.53	1.71	1.56	1.44	1.44	1.73	1.54	1.67	1.45	1.81	1.56	2.08
II	1.02	1.20	1.20	1.47	1.31	1.85	2.00	1.45	1.53	1.47	1.47	1.42
III	1.02	1.14	1.15	1.69	1.42	2.25	1.55	2.03	1.68	1.44	1.99	2.43

	BATCHES		
	I	II	III
C.D. for treatment (T) at 5% =	0.1156*	0.2335*	0.2395*

* Significant

BAR DIAGRAM FOR TREATMENTS

	T_{12}	T_{10}	T_6	T_2	T_8	T_{11}	T_3	T_7	T_1	T_9	T_4	T_5
I BATCH	2.08	1.81	1.73	1.71	1.67	1.56	1.56	1.54	1.53	1.45	1.44	1.44
	T_7	T_6	T_9	T_{10}	T_{11}	T_4	T_8	T_{12}	T_5	T_3	T_2	T_1
II BATCH	2.00	1.85	1.53	1.47	1.47	1.47	1.45	1.42	1.31	1.20	1.20	1.02
	T_{12}	T_6	T_8	T_{11}	T_4	T_9	T_7	T_{10}	T_5	T_3	T_2	T_1
III BATCH	2.43	2.25	2.03	1.99	1.69	1.68	1.55	1.44	1.42	1.15	1.14	1.02

Table ~~22~~ 26. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of phosphorus in leaves per plant of lettuce at three batches of growth.

BATCHES	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	11	12
I	0.331	0.339	0.389	0.363	0.385	0.399	0.398	0.433	0.393	0.385	0.441	0.385
II	0.314	0.363	0.384	0.312	0.379	0.413	0.407	0.427	0.353	0.376	0.458	0.534
III	0.314	0.385	0.407	0.426	0.383	0.424	0.483	0.483	0.353	0.317	0.465	0.490

	BATCHES I	BATCHES II	BATCHES III
C.D. for treatment (T) at 5% =	0.0098*	0.03622*	0.01401*

* Significant

BAR DIAGRAM FOR TREATMENTS

	T_{11}	T_8	T_6	T_7	T_9	T_3	T_5	T_{10}	T_{12}	T_4	T_2	T_1
I BATCH	0.441	0.433	0.399	0.398	0.393	0.389	0.385	0.385	0.385	0.363	0.339	0.331
	T_{12}	T_{11}	T_8	T_6	T_7	T_3	T_5	T_{10}	T_2	T_9	T_1	T_4
II BATCH	0.534	0.458	0.427	0.413	0.407	0.384	0.379	0.376	0.363	0.353	0.314	0.312
	T_{12}	T_7	T_8	T_{11}	T_4	T_6	T_3	T_2	T_5	T_9	T_{10}	T_1
III BATCH	0.490	0.483	0.483	0.465	0.426	0.424	0.407	0.385	0.383	0.353	0.317	0.314

In the second batch of plants, the effect of treatments on the percentage of phosphorus was found significant. Treatment T_{12} showed the highest value and differed critically with all other treatments while T_4 gave the lowest value, equalling the effect of T_1.

The effect of treatments on the percentage of phosphorus was found significant in the third batch of plants. In this batch, treatment T_{12} (as well as T_7 and T_8) gave the maximum value and treatment T_1, together with T_{10}, the minimum.

(iii) Potassium. In the first batch of plants, the effect of treatments on the percentage of potassium in leaves was found significant. Treatment T_{11} showed the maximum percentage of potassium and differed critically with all other treatments, except T_{12}. Treatment T_1 gave the minimum value.

The effect of treatments on the percentage of potassium was found significant in the second batch of plants. Treatment T_{11} gave the highest percentage of leaf potassium and differed critically with all other treatments. Treatment T_1 gave the lowest value.

In the third batch of plants, the effect of treatments on percentage of potassium was found significant. Treatment T_{11} gave significantly higher value and differed critically with all other treatments except T_9 and T_{12}. Treatment T_1 (as also T_2 and T_4) gave the lowest percentage of potassium in this batch.

Table ~~23~~ 27. Effect of different doses of basal and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of potassium in leaves per plant of lettuce at three batches of growth.

BATCHES	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	11	12
I	1.20	1.55	1.47	1.53	1.61	1.73	1.69	1.59	1.67	1.87	2.05	2.03
II	1.17	1.45	1.45	1.55	1.64	1.71	1.92	1.60	2.00	1.53	2.59	2.06
III	1.17	1.43	1.50	1.18	1.67	1.61	1.67	1.51	2.11	1.83	2.17	1.95

	BATCHES		
	I	II	III
C.D. for treatment (T) at 5% =	0.13637*	0.1813*	0.2766*

* Significant

BAR . DIAGRAM FOR TREATMENTS

	T_{11}	T_{12}	T_{10}	T_6	T_7	T_9	T_5	T_8	T_2	T_4	T_3	T_1
I BATCH	2.05	2.03	1.87	1.73	1.69	1.67	1.61	1.59	1.55	1.53	1.47	1.20

	T_{11}	T_{12}	T_9	T_7	T_6	T_5	T_8	T_4	T_{10}	T_3	T_2	T_1
II BATCH	2.59	2.06	2.00	1.92	1.71	1.64	1.60	1.55	1.53	1.45	1.45	1.17

	T_{11}	T_9	T_{12}	T_{10}	T_7	T_5	T_6	T_8	T_3	T_2	T_4	T_1
III BATCH	2.17	2.11	1.95	1.83	1.67	1.67	1.61	1.51	1.50	1.43	1.18	1.17

II. Field experiments

Experiment 3. In this experiment, the effect of various doses of nitrogen, phosphorus and their combinations, applied as basal dressing and as foliar spray, on the yield of grain and cob and on grain quality of three varieties of maize, namely, Ganga-5 (V_1), Ganga-7 (V_2) and Kisan (V_3), was studied. The interaction effect between treatments and varieties was also studied. The data are summarized below and given in Tables ~~26~~ 28 to ~~35~~ 37.

1. Yield characteristics

(i) Cob yield per plant. The effect of different treatments, response of different varieties, and the interaction effect (treatment x variety) on cob yield per plant was found significant (Table ~~26~~ 28).

All treatments produced significantly more cob per plant than the control (T_1) (plants receiving neither basal dressing nor spray of nutrients). Treatment T_7 gave the highest value but showed equal effect with T_5 and T_4. The remaining treatments produced equal effect, except, as noted above, the control (T_1) which gave the minimum value and differed critically with all the other treatments.

Varietal response for cob yield per plant was found significant. Variety V_1 gave the maximum value and was followed by V2 and V_3 in that order. These varieties showed critical differences with each other.

Table ~~26~~ 28. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on cob yield of three varieties of maize (g/plant).

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	19.96	24.73	21.76	22.96	23.26	22.40	28.13	22.76	23.25
V_2	20.00	19.43	21.20	24.96	19.90	20.86	22.13	18.26	20.84
V_3	12.13	16.50	19.33	18.26	23.70	18.16	16.83	19.06	18.00
MEAN	17.36	20.22	20.76	22.06	22.28	20.47	22.36	20.03	

C.D. for treatment (T) at 5% = 0.8834*
C.D. for variety (V) at 5% = 0.5414*
C.D. for interaction (TxV) at 5% = 1.5388*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_7	T_5	T_4	T_3	T_6	T_2	T_8	T_1
22.36	22.28	22.06	20.76	20.47	20.22	20.03	17.36

Similarly, the interaction effect between treatment and variety was found significant. Considering all combinations, it was found that variety V_1 interacted with treatment T_7 to give the maximum value of cob yield per plant. The effect of this combination (T_7 x V_1) critically differed with that of all other combinations.

(ii) <u>Cob yield per hectare</u>. The effect of treatments on average cob yield produced per hectare was found significant (Table ~~27~~ 29). All treatments gave significant higher cob yield per hectare than the control. The treatment T_7 resulted in maximum yield which differed critically with that of all other treatments except T_5 and T_4. The treatment T_1 (control) gave minimum value for cob yield per hectare and differed critically with all other treatments in this respect.

Varietal response, regarding the cob yield per hectare, was also found significant. Variety V_1 gave the maximum value. It was followed by variety V_2 and the minimum value was recorded for the variety V_3. These three varieties differed critically with each other in their response.

The interaction effect (treatment x variety) was found significant, the combination T_7 x V_1 producing best results. Its effect differed critically with that of all other combinations. The lowest yield of cob per hectare was given by the combination T_1 x V_3. This also differed critically with all other

Table ~~27~~ 29. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on cob yield of three varieties of maize (q/ha).

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	12.836	15.900	13.992	14.764	14.957	14.400	18.085	14.635	14.946
V_2	12.857	12.493	13.628	16.050	12.792	13.414	14.228	11.743	13.400
V_3	7.800	10.607	12.428	11.743	15.233	11.657	10.821	12.257	11.568
MEAN	11.164	13.000	13.349	14.185	14.327	13.157	14.378	12.878	

C.D. for treatment (T) at 5% = 0.5756*
C.D. for variety (V) at 5% = 0.3534*
C.D. for interaction (TxV) at 5% = 0.9974*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_7	T_5	T_4	T_3	T_6	T_2	T_8	T_1
14.378	14.327	14.185	13.349	13.157	13.000	12.878	11.164

combinations.

(iii) Grain yield per plant. Grain yield per plant was found to increase significantly with the application of nutrients (Table ~~28~~ 30). Treatment T_7 gave the maximum value and differed critically with all other treatments. Treatment T_6 gave the value next to T_7, while T_2 and T_1 gave the lowest values.

Varietal differences and the interaction between treatment and variety were found to be significant. Highest grain yield per plant was recorded in variety V_1 followed by V_2 and V_3 in that order. The best combination regarding grain yield per plant was $T_7 \times V_1$. The effect of this combination was critically higher than that of all other treatments. The combinations $T_1 \times V_3$, $T_2 \times V_3$ and $T_8 \times V_2$, which had equal effect, gave the poorest grain yield per plant.

(vi) Grain yield per hectare. All treatments produced significantly more grain per hectare than the control (Table ~~29~~ 31). The treatment T_7 gave maximum yield and differed critically with all other treatments. Treatment T_6 gave the response next to treatment T_7. Treatment T_2 showed the minimum response which was equal to that of the control (T_1).

Differences among the varieties were significant and the average yield varied in the order: $V_1 > V_2 > V_3$.

Table ~~28~~ 30. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on grain yield of three varieties of maize (g/plant).

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	73.93	78.96	84.43	91.66	90.86	84.66	115.16	85.30	88.12
V_2	73.80	69.43	88.93	89.46	92.80	105.10	91.06	65.86	84.55
V_3	67.36	66.10	88.53	83.86	81.80	84.86	91.50	89.80	81.72
MEAN	71.70	71.50	87.30	88.33	88.48	91.54	99.24	80.32	

C.D. for treatment (T) at 5% = 1.8807*
C.D. for variety (V) at 5% = 1.1398*
C.D. for interaction (TxV) at 5% = 3.2486*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_7	T_6	T_5	T_4	T_3	T_8	T_1	T_2
99.24	91.54	88.48	88.33	87.30	80.32	71.70	71.50

31

Table ~~29~~. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on grain yield of three varieties of maize (q/ha).

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	47.528	50.764	54.278	58.928	58.414	54.428	74.593	54.836	56.721
V_2	47.443	44.635	57.171	57.514	59.657	67.564	58.542	42.343	54.358
V_3	43.307	42.493	56.914	53.914	52.585	54.557	58.821	57.728	52.540
MEAN	46.093	45.964	56.121	56.785	56.885	58.849	63.985	51.635	

C.D. for treatment (T) at 5% = 1.2624*
C.D. for variety (V) at 5% = 0.7722*
C.D. for interaction (TxV) at 5% = 2.1857*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_7	T_6	T_5	T_4	T_3	T_8	T_1	T_2
63.985	58.849	56.885	56.785	56.121	51.635	46.093	45.964

The interaction effect between treatment and variety was found to be significant. Highest grain yield per hectare was recorded in the combination $T_7 \times V_1$, whereas the combinations $T_8 \times V_2$, $T_2 \times V_3$, and $T_1 \times V_3$ gave the poorest performance.

2. Grain quality

The effects of the eight nutrient treatments on the quality of grain in the three varieties of maize are summarized in Tables ~~30~~ 32 to ~~35~~ 37 and are described briefly below:

(i) Soluble carbohydrates. The response of the three varieties of maize to the various treatments regarding the percentage of soluble carbohydrates in the grain was found to be significant (Table ~~30~~ 32). Treatment T_3 gave the maximum value and differed critically with all other treatments, whereas treatment T_6 gave the next lower value. Treatment T_2 gave the minimum value.

Varietal response for the percentage of soluble carbohydrates in the grain was found significant. Variety V_3 gave the maximum value and was followed by V_1 and V_2 which had equal effect.

The interaction effect between treatment and variety was also found to be significant. Considering all combinations, $T_6 \times V_2$ gave the maximum percentage of soluble carbohydrates in the grain and $T_8 \times V_2$, the minimum.

Table 32 30. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of soluble carbohydrates in three varieties of maize.

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	3.99	3.57	4.49	4.38	3.91	4.25	4.02	4.74	4.16
V_2	4.02	2.93	5.62	3.28	3.44	5.81	4.70	2.82	4.08
V_3	4.84	4.40	5.54	4.89	4.82	4.98	5.46	4.84	4.96
MEAN	4.28	3.61	5.22	4.18	4.06	5.00	4.73	4.13	

C.D. for treatment (T) at 5% = 0.1710*
C.D. for variety (V) at 5% = 0.1140*
C.D. for interaction (TxV) at 5% = 0.3135*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_3	T_6	T_7	T_1	T_4	T_8	T_5	T_2
5.22	5.00	4.73	4.28	4.18	4.13	4.06	3.61

(ii) <u>Insoluble carbohydrates</u>. The effect of treatments on the percentage of insoluble carbohydrates in the grain was significant (Table ~~31~~ 33). It is evident from the table that treatment T_5 gave the highest percentage of insoluble carbohydrates. The lowest value was recorded for the control (T_1).

The varietal differences were also found significant. The highest value for insoluble carbohydrate content of the grain was recorded in variety V_3 but it critically differed with the variety V_1 only, which gave the minimum value for insoluble carbohydrate content.

The maximum insoluble carbohydrate content was recorded for the combination $T_2 \times V_3$ and the minimum for $T_2 \times V_1$ and $T_1 \times V_1$.

(iii) <u>Total carbohydrates</u>. The effect of treatments on total grain carbohydrates in the three varieties of maize was found significant (Table ~~32~~ 34). Treatment T_5 gave the highest value in this regard. It was critically different from the values for all other treatments.

The varietal differences were also found significant. As is evident from the table, the highest value for percentage of total carbohydrate content of the grain was recorded in variety V_3. It differed critically with V_2 and V_1, the latter giving the lowest value for total carbohydrate percentage in the grain.

Table ~~31~~ 33. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of insoluble carbohydrates in three varieties of maize.

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	59.20	58.08	59.54	69.73	80.66	66.53	61.20	62.93	64.73
V_2	68.03	72.40	71.00	69.26	72.60	68.53	73.00	76.70	71.44
V_3	64.00	83.20	76.93	64.80	75.06	65.86	73.40	77.33	72.57
MEAN	63.74	71.22	69.16	67.93	76.11	66.97	69.20	72.32	

C.D. for treatment (T) at 5% = 2.4792*
C.D. for variety (V) at 5% = 1.5103*
C.D. for interaction (TxV) at 5% = 4.3029*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_5	T_8	T_2	T_7	T_3	T_4	T_6	T_1
76.11	72.32	71.22	69.20	69.16	67.93	66.97	63.74

34

Table ~~32~~. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of total carbohydrates in three varieties of maize.

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	MEAN
V_1	63.19	61.59	64.24	74.11	81.24	70.78	65.22	67.67	68.50
V_2	72.06	75.33	76.62	72.54	76.04	74.34	77.70	79.52	75.52
V_3	68.84	87.60	82.48	69.69	79.89	70.80	78.86	82.17	77.54
MEAN	68.03	74.84	74.44	72.11	79.06	71.97	73.93	76.45	

C.D. for treatment (T) at 5% = 2.7926*
C.D. for variety (V) at 5% = 1.7098*
C.D. for interaction (TxV) at 5% = 4.8728*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_5	T_8	T_2	T_3	T_7	T_4	T_6	T_1
79.06	76.45	74.84	74.44	73.93	72.11	71.97	68.03

When two treatment means at the same level of variety were compared, the response was noted to be significant. Maximum value was recorded in the variety V_3 with the treatment T_2. The minimum value was noted for the combination $T_2 \times V_1$.

(iv) Soluble proteins. The effect of treatments on the percentage of soluble proteins in the grain of the three varieties of maize was found non-significant but varietal response was found significant (Table ~~33~~ 35). Variety V_2 gave the maximum value and V_1, the minimum, but variety V_3 did not differ critically with V_2 in its response.

The interaction effect between treatment and variety was also found to be significant. Considering all combinations, $T_3 \times V_2$ gave the maximum percentage of soluble proteins in the grain, the minimum value being obtained by the combination $T_7 \times V_1$ but the effects did not differ critically.

(v) Insoluble proteins. The effect of treatments on the percentage of insoluble proteins in the grain of the three varieties of maize was significant (Table ~~34~~ 36). It is clear from the table that treatment T_6 gave the highest percentage of insoluble proteins. The effect of this treatment differed critically with that of all other treatments, except T_2.

Varietal response regarding the percentage of insoluble proteins was also significant. Variety V_2 gave the maximum value

Table ~~33~~ 35. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of soluble proteins in three varieties of maize.

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	1.237	1.242	1.457	1.068	1.125	1.201	0.966	1.106	1.175
V_2	2.960	3.093	3.226	2.920	2.586	3.200	2.986	2.313	2.910
V_3	2.406	2.853	2.626	2.153	2.760	2.986	2.540	2.133	2.557
MEAN	2.201	2.396	2.437	2.047	2.157	2.462	2.164	1.850	

C.D. for treatment (T) at 5% = N.S.
C.D. for variety (V) at 5% = 0.9404*
C.D. for interaction (TxV) at 5% = 2.7071*

* Significant

N.S. Non-significant

Table ~~34~~ 36. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of insoluble proteins in three varieties of maize.

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	3.35	4.57	3.85	3.59	2.72	4.96	5.47	4.16	4.08
V_2	6.56	7.00	7.80	6.06	5.13	7.20	6.21	5.33	6.41
V_3	5.33	5.80	5.26	5.60	5.81	6.13	5.35	5.78	5.63
MEAN	5.08	5.79	5.63	5.08	4.55	6.09	5.67	5.09	

C.D. for treatment (T) at 5% = 0.3135*
C.D. for variety (V) at 5% = 0.1995*
C.D. for interaction (TxV) at 5% = 0.5699*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_2	T_7	T_3	T_8	T_4	T_1	T_5
6.09	5.79	5.67	5.63	5.09	5.08	5.08	4.55

and was followed by V_3 and V_1 in that order. All the three varieties showed critical difference with each other.

The interaction effect between treatment and variety was also found significant. Considering all combinations, $T_3 \times V_2$ gave the highest value for the percentage of insoluble proteins in the grain but $T_6 \times V_2$ and $T_2 \times V_2$ also gave equally good performance. The minimum value was recorded for the combination $T_5 \times V_1$.

(vi) <u>Total proteins</u>. The effect of treatments on the percentage of total grain proteins was found significant (Table ~~35~~ 37). The highest value was obtained with T_6 whose effect was equalled by T_3 and T_2. The lowest value was recorded for T_5 and T_8.

The varietal differences were also found significant. As is clear from the table, the highest value for percentage of total protein content of the grain was recorded in variety V_2 and the minimum in variety V_1. All the three varieties differed critically with each other in this regard.

When two treatment means at the same level of variety were compared, the response was noted to be significant. The maximum interaction effect was recorded in the variety V_2 with the treatment T_3 and the minimum for the combination $T_5 \times V_1$.

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Table 35. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of total proteins in three varieties of maize.

VARIETIES	TREATMENTS								MEAN
	1	2	3	4	5	6	7	8	
V_1	4.591	5.812	5.314	4.662	3.846	6.161	6.436	5.272	5.262
V_2	9.726	10.093	11.026	8.986	7.720	10.400	9.203	7.646	9.350
V_3	7.740	8.320	7.893	7.753	8.576	9.120	7.890	7.916	8.151
MEAN	7.352	8.075	8.078	7.134	6.714	8.560	7.843	6.945	

C.D. for treatment (T) at 5% = 0.3761*
C.D. for variety (V) at 5% = 0.2308*
C.D. for interaction (TxV) at 5% = 0.6526*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_3	T_2	T_7	T_1	T_4	T_8	T_5
8.560	8.078	8.075	7.843	7.352	7.134	6.945	6.714

<u>Experiment 4</u>. In this experiment, the effect of different levels of spray phosphorus with three combinations of nitrogen and phosphorus applied as basal dressing, on the yield of grain and cob and on grain quality of three varieties of maize, namely Ganga-5 (V_1), Ganga-7 (V_2) and Kisan (V_3), grown under field conditions, was studied. The interaction effect between different treatments and these three varieties was also studied. The data are given in Tables 38 to 47 and are summarized below:

1. <u>Yield characteristics</u>

(i) <u>Cob yield per plant</u>. The effect of different treatments on the yield of cob per plant was found significant (Table 38). Treatment T_8 gave the maximum value which was statistically equal to those of treatments T_7, T_3, T_6, T_1, T_2, T_5 and T_{10}.

Varietal response as well as interaction between treatment and variety was found non-significant.

(ii) <u>Cob yield per hectare</u>. Effect of treatment on average cob yield produced per hectare was found significant (Table 39). Treatment T_8 showed the maximum yield which was statistically equal to those of treatments T_7, T_3, T_6, T_1, T_2, T_5 and T_{10}.

Varietal response as well as the interaction between treatment and variety was found non-significant.

Table 38. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on cob yield of three varieties of maize (g/plant).

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	MEAN
V_1	14.00	14.20	18.83	16.56	14.66	14.60	17.40	22.96	11.73	15.16	9.46	10.50	15.00
V_2	16.93	17.60	15.10	13.23	19.83	17.16	17.36	16.90	10.43	13.26	13.66	13.70	15.43
V_3	17.66	16.70	17.46	12.06	11.63	17.60	17.50	15.70	13.76	14.73	11.23	12.83	14.90
MEAN	16.20	16.16	17.13	13.95	15.37	16.45	17.42	18.52	11.93	14.38	11.45	12.34	

C.D. for treatment (T) at 5% = 4.349*
C.D. for variety (V) at 5% = 2.175*
C.D. for interaction (TxV) at 5% = 7.569*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_7	T_3	T_6	T_1	T_2	T_5	T_{10}	T_4	T_{12}	T_9	T_{11}
18.52	17.42	17.13	16.45	16.20	16.16	15.37	14.38	13.95	12.34	11.97	11.45

Table 39. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on cob yield of three varieties of maize (q/ha).

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	MEAN
V_1	9.00	9.12	12.10	10.64	9.42	9.38	11.18	14.76	7.54	9.74	6.08	6.74	9.64
V_2	10.88	11.31	9.70	8.50	12.74	11.03	11.16	10.86	6.70	8.52	8.78	8.80	9.91
V_3	11.35	10.73	11.22	7.75	7.47	11.31	11.24	10.09	8.84	9.46	7.21	8.24	9.57
MEAN	10.41	10.39	11.01	8.96	9.88	10.57	11.19	11.90	7.69	9.24	7.35	7.93	

C.D. for treatment (T) at 5% = 2.796*
C.D. for variety (V) at 5% = 1.384*
C.D. for interaction (TxV) at 5% = 4.858*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_7	T_3	T_6	T_1	T_2	T_5	T_{10}	T_4	T_{12}	T_9	T_{11}
11.90	11.19	11.01	10.57	10.41	10.39	9.88	9.24	8.96	7.93	7.69	7.35

(iii) Grain yield per plant. Grain yield was found to be increased significantly with the application of nutrients (Table 40). Treatment T_8 gave the maximum value and differed critically with all other treatments. Treatment T_3 gave the next lower value but statistically its effect was equal to those of T_7, T_2, T_6 and T_4. Treatment T_9 produced least grain, the effect being equal to that of T_{11}.

Varietal differences were also found to be significant. Variety V_3 gave the maximum value and was followed by V_2 and V_1 in that order.

The interaction effect between treatment and variety was found to be significant. Maximum grain per plant was produced by variety V_3 with the treatment T_8, whereas $T_9 \times V_2$ gave the lowest value.

(iv) Grain yield per hectare. The effect of treatments on grain yield per hectare was found significant (Table 41). Treatment T_8 gave the maximum yield and differed critically with all other treatments. Treatments T_3 (and, statistically, T_7, T_2, T_6 and T_4) gave the response next to treatment T_8, while treatment T_9 showed the minimum response which was equal to that of T_{11}.

The varietal differences were also found significant. The highest value for grain yield per hectare was recorded in the variety V_3. The minimum value was found in the variety V_1. Grain yield per hectare in these three varieties was in the order:

Table 40. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on grain yield of three varieties of maize (g/plant).

VARIETIES	TREATMENTS												MEAN
	1	2	3	4	5	6	7	8	9	10	11	12	
V_1	59.56	67.70	78.83	68.50	62.60	66.36	70.63	87.16	52.46	63.26	66.46	70.46	67.83
V_2	64.10	72.53	83.46	91.63	63.53	74.60	85.93	101.60	50.03	64.16	58.00	77.46	74.08
V_3	85.23	92.30	84.80	63.96	65.13	87.83	86.86	111.03	56.23	63.76	54.80	63.56	76.29
MEAN	69.63	77.51	82.36	74.70	63.75	76.26	81.14	99.93	53.57	63.73	59.75	70.50	

C.D. for treatment (T) at 5% = 8.303*
C.D. for variety (V) at 5% = 4.152*
C.D. for interaction (TxV) at 5% = 14.375*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_3	T_7	T_2	T_6	T_4	T_{12}	T_1	T_5	T_{10}	T_{11}	T_9
99.93	82.36	81.14	77.51	76.26	74.70	70.50	69.63	63.75	63.73	59.75	53.75

Table 41. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on grain yield of three varieties of maize (q/ha).

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	MEAN
V_1	38.29	43.52	50.67	44.03	40.23	42.66	45.40	56.03	33.72	40.66	42.71	45.29	43.60
V_2	41.20	46.62	53.65	59.23	40.83	47.95	55.24	65.30	33.44	41.24	37.27	49.79	47.65
V_3	54.79	59.33	54.51	41.11	41.86	56.45	55.84	71.37	36.14	42.64	35.22	40.86	49.17
MEAN	44.76	49.82	52.94	48.12	40.97	49.02	52.16	64.23	34.43	41.51	38.40	45.31	

C.D. for treatment (T) at 5% = 5.394*
C.D. for variety (V) at 5% = 2.697*
C.D. for interaction (TxV) at 5% = 9.348*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_3	T_7	T_2	T_6	T_4	T_{12}	T_1	T_{10}	T_5	T_{11}	T_9
64.23	52.94	52.16	49.82	49.02	48.12	45.31	44.76	41.51	40.97	38.40	34.43

$V_3 > V_2 > V_1$.

The interaction effect between treatment and variety was also found significant. Highest grain yield per hectare was recorded in the combination $T_8 \times V_3$ and the lowest in $T_9 \times V_2$.

2. Grain quality

The effect of the twelve nutrient treatments on the quality of grain in the three varieties of maize is summarised in Tables 42 to 47 and is described briefly below:

(i) Soluble carbohydrates. The effect of various treatments on the percentage of soluble carbohydrates in the grain was found to be significant (Table 42). The treatment T_7 resulted in the highest percentage of soluble carbohydrates and differed critically in this respect with all other treatments, except T_4 and T_{10}. Treatment T_6 showed the lowest value.

Varietal response for the percentage of soluble carbohydrates in the grain was found significant, the three varieties showing critical difference with each other. Variety V_2 gave maximum value and was followed by V_3 and V_1 in that order.

The interaction effect between treatment and variety was also found to be significant. Considering all combinations, $T_8 \times V_1$ gave the maximum and $T_2 \times V_1$, the minimum percentage of soluble carbohydrates in the grain.

Table 42. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of soluble carbohydrates in three varieties of maize.

VARIETIES	TREATMENTS												MEAN
	1	2	3	4	5	6	7	8	9	10	11	12	
V_1	3.30	2.19	3.76	3.64	3.42	3.80	5.42	6.21	3.90	4.57	2.52	5.12	3.99
V_2	4.86	5.70	3.82	6.07	5.26	3.52	4.55	2.47	4.53	4.38	6.16	4.31	4.63
V_3	4.63	4.46	5.58	4.72	4.52	4.62	4.57	3.91	4.06	4.93	3.76	3.87	4.47
MEAN	4.26	4.12	4.39	4.81	4.40	3.98	4.85	4.20	4.16	4.63	4.15	4.43	

C.D. for treatment (T) at 5% = 0.395*
C.D. for variety (V) at 5% = 0.198*
C.D. for interaction (TxV) at 5% = 0.706*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_7	T_4	T_{10}	T_{12}	T_5	T_3	T_1	T_8	T_9	T_{11}	T_2	T_6
4.85	4.81	4.63	4.43	4.40	4.39	4.26	4.20	4.16	4.15	4.12	3.98

(ii) Insoluble carbohydrates. The effect of treatments on the percentage of insoluble carbohydrates in the grain of the three varieties of maize was found significant (Table 43). Treatment T_6 gave the highest percentage of insoluble carbohydrates but the effect was equal to that of T_8, T_5, T_3, T_{10}, T_2, T_{11} and T_{12}. The lowest value was given by treatment T_9, the effect being equalled by T_4 and T_7.

The varietal differences were also found significant. The highest value for insoluble carbohydrate content of the grain was recorded in variety V_2 but the response was equal to that of variety V_1. Variety V_3 differed critically with these two varieties in this respect.

When two treatment means at the same level of variety were compared, the highest percentage of insoluble carbohydrates was recorded in the combination $T_8 \times V_1$ and the lowest, in $T_7 \times V_3$.

(iii) Total carbohydrates. The effect of treatments on total carbohydrates was found significant (Table 44). Treatment T_6 gave the highest percentage but all other treatments, except T_7 and T_9, had an effect equal to it.

The varietal differences were also found significant. As is evident from the table, the highest value for percentage of total carbohydrate content of the grain was recorded in

Table 43. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of insoluble carbohydrates in three varieties of maize.

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	MEAN
V_1	72.66	74.75	75.42	71.54	80.41	81.41	81.00	83.95	65.33	80.62	80.04	62.66	75.81
V_2	77.46	75.42	80.87	76.21	74.12	80.50	70.96	76.45	76.46	75.91	69.75	81.42	76.29
V_3	72.54	76.00	72.04	74.16	80.42	75.42	62.50	76.25	66.54	69.83	75.83	79.58	73.42
MEAN	74.22	75.39	76.11	73.97	78.32	79.11	71.48	78.88	69.44	75.45	75.20	74.55	

C.D. for treatment (T) at 5% = 4.773*
C.D. for variety (V) at 5% = 2.386*
C.D. for interaction (TxV) at 5% = 8.275*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_8	T_5	T_3	T_{10}	T_2	T_{11}	T_{12}	T_1	T_4	T_7	T_9
79.11	78.88	78.32	76.11	75.45	75.39	75.20	74.55	74.22	73.97	71.48	69.44

Table 44. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of total carbohydrates in three varieties of maize.

VARIETIES	TREATMENTS												MEAN
	1	2	3	4	5	6	7	8	9	10	11	12	
V_1	75.97	76.94	79.18	75.19	83.48	85.22	86.42	90.16	69.24	85.20	82.57	67.79	79.81
V_2	82.32	81.12	84.70	82.28	79.38	84.02	75.51	78.92	80.99	80.29	75.91	85.73	80.93
V_3	77.17	80.46	77.62	78.89	84.94	80.04	67.08	80.16	70.61	74.77	79.59	83.46	77.90
MEAN	78.49	79.51	80.50	78.78	82.72	83.09	76.33	83.07	73.61	80.08	79.36	78.99	

C.D. for treatment (T) at 5% = 4.773*
C.D. for variety (V) at 5% = 2.386*
C.D. for interaction (TxV) at 5% = 8.247*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_6	T_8	T_5	T_3	T_{10}	T_2	T_{11}	T_{12}	T_4	T_1	T_7	T_9
83.09	83.07	82.72	80.50	80.08	79.51	79.36	78.99	78.78	78.49	76.33	73.61

variety V_2 but it did not differ critically with V_1. Variety V_3, which gave a lower value for total carbohydrate percentage in the grain, differed critically with the variety V_2.

When two treatment means at the same level of variety were compared, the response was noted to be significant. Maximum effect of interaction was recorded in the variety V_1 with the treatment T_8, and the minimum, in variety V_3 with treatment T_7.

(iv) Soluble proteins. The effect of various treatments on the percentage of soluble proteins in the grain was found significant (Table 45). Treatment T_8 gave the maximum value. It differed critically with the values obtained with all other treatments, except T_9 and T_1. Treatment T_2 (as also, T_{10}, T_5, T_3 and T_6) gave the minimum value for the percentage of soluble proteins in the grain.

Varietal response for the percentage of soluble proteins was found significant. Variety V_2 gave the maximum value but the effect was equal to that of variety V_3. The variety V_1 gave the minimum soluble protein percentage in the grain.

The interaction effect between treatment and variety was also found to be significant. Considering all treatments, $T_9 \times V_2$ gave the maximum percentage of soluble proteins in the grain in comparison with the other combinations, the minimum

Table 45. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of soluble proteins in three varieties of maize.

VARIETIES	TREATMENTS												MEAN
	1	2	3	4	5	6	7	8	9	10	11	12	
V_1	1.34	0.96	1.06	1.45	1.04	0.95	1.32	2.03	1.14	1.08	1.01	1.30	1.22
V_2	2.63	0.98	1.15	1.56	1.11	1.05	1.39	2.31	2.86	1.21	2.31	1.34	1.66
V_3	2.05	0.96	1.07	1.58	1.23	1.02	1.36	2.15	2.33	1.20	2.51	1.41	1.57
MEAN	2.01	0.97	1.09	1.53	1.13	1.01	1.36	2.16	2.11	1.16	1.94	1.35	

C.D. for treatments (T) at 5% = 0.198*
C.D. for variety (V) at 5% = 0.099*
C.D. for interaction (TxV) at 5% = 0.339*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_9	T_1	T_{11}	T_4	T_7	T_{12}	T_{10}	T_5	T_3	T_6	T_2
2.16	2.11	2.01	1.94	1.53	1.36	1.35	1.16	1.13	1.09	1.01	0.97

value being obtained with the combination T_6 x V_1.

(v) Insoluble proteins. The effect of treatments on the percentage of insoluble proteins in the grain was found significant (Table 46). It is clear from the table that treatment T_8 gave the highest percentage of insoluble proteins. This treatment differed critically with all other treatments. The lowest value was obtained with treatment T_9 but its effect was equal to that of treatments T_{12} and T_5.

Varietal response regarding the percentage of insoluble proteins was also significant. Variety V_2 gave maximum value and was followed by V_3 and V_1. All the three varieties showed critical difference with each other.

The interaction effect between treatment and variety was also found to be significant. Considering all combinations, T_8 x V_2 gave the highest value. The minimum value was recorded for the combination T_9 x V_1.

(vi) Total proteins. The effect of various treatments on the percentage of total proteins was found significant (Table 47). Treatment T_8 gave the highest value and differed critically with all other treatments. Treatment T_9 gave the lowest value but its effect was equal to that of T_5.

The varietal difference was also found significant. The highest value for percentage of total protein content of

Table 46. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of insoluble proteins in three varieties of maize.

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	MEAN
V_1	3.79	4.08	4.33	4.93	3.48	3.83	3.94	6.12	3.32	4.25	4.40	3.61	4.17
V_2	5.86	6.17	6.49	6.03	5.72	6.44	6.42	7.81	4.29	5.73	5.83	5.70	6.04
V_3	5.71	6.00	6.21	5.88	5.66	6.40	6.32	7.60	3.80	5.45	5.23	5.71	5.83
MEAN	5.12	5.42	5.68	5.61	4.95	5.56	5.56	7.17	3.80	5.14	5.15	5.00	

C.D. for treatment (T) at 5% = 0.311*
C.D. for variety (V) at 5% = 0.155*
C.D. for interaction (TxV) at 5% = 0.565*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_3	T_4	T_6	T_7	T_2	T_{11}	T_{10}	T_1	T_{12}	T_5	T_9
7.17	5.68	5.61	5.56	5.56	5.42	5.15	5.14	5.12	5.00	4.95	3.80

Table 47. Effect of soil- and foliar-applied nitrogen, phosphorus and their combinations, on the percentage of total proteins in three varieties of maize.

VARIETIES	TREATMENTS 1	2	3	4	5	6	7	8	9	10	11	12	MEAN
V_1	5.14	5.05	5.40	6.39	4.52	4.79	5.26	8.15	4.64	5.34	5.41	4.91	5.40
V_2	8.49	7.16	7.65	7.59	7.17	7.50	7.82	10.12	7.15	6.94	8.14	7.05	7.73
V_3	7.77	6.96	7.28	7.46	6.89	7.42	7.69	9.75	6.10	6.65	7.75	7.12	7.40
MEAN	7.13	6.39	6.77	7.15	6.19	6.57	6.92	9.34	5.91	6.31	7.10	6.36	

C.D. for treatment (T) at 5% = 0.367*
C.D. for variety (V) at 5% = 0.184*
C.D. for interaction (TxV) at 5% = 0.650*

* Significant

BAR DIAGRAM FOR TREATMENTS

T_8	T_4	T_1	T_{11}	T_7	T_3	T_6	T_2	T_{12}	T_{10}	T_5	T_9
9.34	7.15	7.13	7.10	6.92	6.77	6.57	6.39	6.36	6.31	6.19	5.91

the grain was recorded in variety V_2 and the minimum in variety V_1. All the three varieties differed critically with each other in this regard.

When two treatment means at the same level of variety were compared, the response was noted to be significant. The maximum interaction effect was recorded in the variety V_2 with the treatment T_8 and the minimum, for the combination $T_5 \times V_1$.

C H A P T E R V

DISCUSSION

The ultimate purpose of all agro-physiological investigations is to improve the productivity of a crop, through an intimate knowledge of the factors which control the processes of plant growth and yield. Genetic constitution, is no doubt primarily responsible in determining the pattern of growth, yield and even nutrient composition of a plant variety. However, environmental factors affect the expression of these traits to such a large extent that, for better yield returns, proper handling of these factors becomes a must. Yield of plants is thus a resultant of the interaction between its habit and the habitat. Availability and efficient utilization of nutrients being among the most important aspects of the latter, a study of the nutrient requirements in relation to growth and yield of different varieties of a crop plant is important, both from agronomic as well as breeding point of view.

Three varieties of barley (Hordeum vulgare L.) namely, RS 6 (V_1), IB 226 (V_2) and K 572/10 (V_3); one variety of lettuce namely, Suttons Golden Ball and three varieties of maize namely, Ganga-5 (V_1), Ganga-7 (V_2) and Kisan (V_3) were selected to study their responses to application of various combinations of nitrogen and phosphorus. The observations included the effect of different nutrient environments, created by using various combinations and levels of these nutrients on the growth, yield and nutrient composition of these varieties. The plants were grown in sand culture (barley) in soil culture (lettuce) and in the field (maize). Results obtained have been given in the preceding chapter and are discussed below in the light of the findings of other workers on cereals, vegetables and related crops.

In barley the effect of treatments on the vegetative characters was mostly found to be significant (Tables 4 to 8). The pattern of the effect, however, depended on the strength of the nutrient solution added to the sand. Thus, the solution containing full strength of NPK enhanced tiller and leaf number of plants as well as fresh and dry weight of the tops at both stages of growth, irrespective of the spray treatments. In the other batch of plants, grown with nutrient solution of 1/2 strength, the effects were of a lower order than in the first batch, spray of water, N, P or N + P again affecting the characters equally.

The results are in conformity with the findings on barley of Brenchley (1914), Hoagland (1919), Hoagland and Martin (1923), Gregory (1926) and Brenchley (1929), among the earlier workers and those of Van Der Paauw (1952), Ranjan and Das (1957), Grunes et al. (1958), Das (1959), Lal and Subba Rao (1959), Sen (1960), Safaya (1971) and Samiullah (1971).

The data assume additional importance as the three varieties of barley selected for this experiment belong to the newly evolved, high yielding cultivars which require larger quantities of nutrient elements for optimum growth (and yield) than the doses hitherto prescribed for earlier varieties.

The pattern of response of yield characteristics to treatments was more clear-cut than those of vegetative characteristics (Tables ~~9~~ 15 to ~~12~~ 18). Ear number, as well as ear weight, grain weight and straw weight per plant, was significantly enhanced by spray, the best results being obtained with the spray of N at 8th week after sowing on plants grown with full basal nutrients (T_6). This performance was followed by other spray treatments on plants of the same series (full strength nutrient solution), viz. T_3, T_4, T_5 and T_7 to variable degrees for each of the characters. An observation of importance is that the control (T_1) almost invariably gave the poorest response, for all yield characters and T_2 for grain yield. These observations point not only towards a higher nutrient requirement but also higher requirement for N than for P by these varieties, as spray treatments containing N alone or in combination with P (T_4, T_6 and T_7) had a definite edge over those containing P alone (T_2 and T_5) with regard to the four yield characteristics studied and in particular, the grain yield.

When the effect of spray treatments on plants receiving 1/2 strength of nutrients is considered, the plants seem to have been starved of N and P that is why spray treatments (T_9 to T_{14}) almost invariably resulted more or less in increased yield characteristics as compared with the control (T_8) receiving the spray of water only. Among plants of this batch also, the best response was to a spray of N at 4th week after sowing (T_{10}) with treatments T_9 and T_{12} (spray of P alone) giving considerably poorer responses which tends to confirm the assumption made above.

The findings are not altogether new. Earlier workers including Bergstrom (1948), Van Der Paauw (1952), Das (1959), Bhatnagar et al. (1960), Safaya (1971), Samiullah (1971) and Afridi and Samiullah (1973a) have also reported a linear increase in various growth and yield characters of barley with increasing nutrient levels, within limits.

The leaf N and P concentrations were found to be affected significantly by spray treatments at both heading and milky grain stages but the effects were equal statistically to those of the controls (T_1 or T_8) in the two batches of plants grown with full strength or 1/2 strength of nutrient solution, respectively. This might have been responsible for the effects of various spray treatments on vegetative characters being statistically equal to those of the respective control (T_1 or T_8) noted above.

Inspite of this, it is remarkable that the yield characteristic showed considerable variation as a result of different spray treatments among themselves (T_2 to T_7) and (T_9 to T_{14}) as well as with their respective controls (T_1 or T_8) which showed the poorest response.

One reason for this discrepancy between the differential response of the growth and yield characteristics to the various treatments may be that the manifestation of their effect is delayed in the (high yielding) varieties selected for this experiment. Another reason may be afforded by the high capacity of these varieties to absorb and utilise the nutrients for a longer period, as well as at a higher rate, than that of the traditional varieties. It must be admitted that it might have been interesting if the effects of treatments on the vegetative characteristics were noted at least once after the milky grain stage also while the grain-filling process was still continuing. It is likely that such readings might have elucidated the position and helped in resolving the discrepancy noted above.

The three varieties of barley exhibited significant differences in all growth characteristics, except dry weight, at both samplings (Tables ~~4~~ 10 to ~~8~~ 14). It may be noted that RS 6 (V_1) occupied a consistent intermediate position regarding all growth characteristics at both stages of growth, whereas, variety IB 226 (V_2) surpassed K 572/10 (V_3) in tallness and fresh weight at both stages and in dry matter production at milky grain stage. On the contrary, K 572/10 (V_3) gave a better account of itself as regards tiller and leaf production at both stages of growth.

It may be noted that K 572/10 (V_3) was dwarfer and had short, less succulent and more upright leaves than the other two varieties, but inspite of these desirable growth characters it was inferior to IB 226 (V_2) with regard to dry matter production (Table ~~8~~ 14). The reason for this poor performance must, therefore, lie elsewhere and is discussed below in connection with the leaf NPK concentration.

Among the yield characteristics, only ear and grain weight were noted to differ significantly from variety to variety. These are the most important characters from the point of view of economic yield. It is also noteworthy that, unlike growth characteristics, variety RS 6 (V_1) performed best as regards these two characters, with the other two varieties showing lower and statistically equal response.

The leaf concentration of NPK at heading stage in the three varieties also revealed the superiority of variety RS 6 (V_1) over the other two varieties, although the N concentration in V_1 was equalled by variety IB 226 (V_2) (Tables ~~13~~ 19 to ~~16~~ 21).

It is well established that the yielding capacity of a plant is genetically controlled, its morphological characters having an important bearing on the final yield (Gregory, 1937; Walton, 1969). In barley stiff, short strawed varieties having upright leaves and a higher tillering and rooting capacity are considered as ideal (Chalam and Venkateswarlu, 1965; Tanner and

Gardner, 1965; Asana, 1970). In the present study, as noted above, variety V_3 was nearly so in structure but its dry weight was less than that of variety V_2 (Table ~~8~~ 14) and its yield less than that of variety V_1 (Tables ~~10~~ 16 and ~~11~~ 17).

Dry matter production is conditioned, to a considerable extent, by the absorption and proper distribution of N at early stages of growth (Gregory and Crowther, 1928; Ranjan and Das, 1957; Grunes _et al_. 1958; Safaya, 1971). In the present study V_3 showed a lower capacity than V_2 to accumulate N in the shoots at the heading stage (Table ~~13~~ 19), which might explain the above observation regarding dry weight (Table ~~8~~ 14). Similarly, P and K are known to affect yield in barley and other cereals (Krantz, 1949; Van Der Paauw, 1952; Lawton and Cook, 1954; Ellis _et al_. 1956; Das, 1959; MacLeod, 1969; Safaya, 1971; Samiullah, 1971; Afridi and Samiullah, 1973a). The higher percentage of these two elements in the leaves of V_1 at heading stage (Tables ~~14~~ 20 and ~~15~~ 21) could, therefore, account for the higher ear and grain weight of this variety (Tables ~~10~~ 16 and ~~11~~ 17).

In lettuce variety Suttons Golden Ball grown in soil (second pot experiment) diameter as well as fresh and dry weight were significantly affected by treatments, as revealed by the data collected at various stages of growth (Tables ~~18~~ 22 to ~~20~~ 24).

It may be noted from Table 18 that the differences in the diameter of plants in the first batch showed a critical effect of the treatments to a greater degree than in the other two batches. Here the plants were sprayed early (10th week after sowing) and also harvested early (14th week). The best effect was that of T_{10} (full basal NPK + N spray). It may be added that spray of nitrogen (T_6 and T_{10}) resulted in slightly better growth than spray of phosphorus (T_7 and T_{11}). This is understandable as nitrogen is known to promote vegetative growth more than phosphorus, particularly at the early stages of growth of all plants and more so of leafy vegetables (Work and Carew, 1970). Among the rest of the treatments in this batch, expectedly T_1 to T_4 (no basal NPK) gave poor performance so did those receiving 1/2 or full basal NPK with spray of water (T_5 and T_9). Apparantly plants getting these treatments could not obtain sufficient NPK to sustain normal growth. However, it is surprising to note that treatments T_8 and T_{12} (plants grown with 1/2 or full basal NPK and sprayed with N + P) had the smallest diameter among the plants of the first batch. This was probably because of the detrimental effect of the high spray concentration of N + P on the tender leaves of a plant like lettuce.

The next two batches of plants were allowed to grow longer (20 weeks). Those in the second batch were sprayed early (10th week) and those in the third as late as 14th.

In the second batch, the effects of treatments were not very clear-cut. None-the-less, T_6, T_{10} and T_{11} were again among those that had the best effect on growth, with some of those responsible for poor growth in the first batch (T_1, T_3, T_5 and T_{12}) having a similar effect on plants of this batch also. It seems from Table 18 that the nitrogen requirement of the plants could be equally well provided by solid or spray nitrogen. However, an over-dose (T_{12}, full NPK + N and P in spray) could be as detrimental for growth as N - starvation (T_1, T_3, T_5 etc.). This argument also seems to apply broadly to the effect of treatments on plants of the third batch.

Strikingly, T_8 (1/2 basal NPK + spray of N + P) had very good effect on the growth of plants in this batch. The leaves of these plants must have become sufficiently mature at the time of spray (14th weeks) to withstand its high concentration. Moreover, the sprayed nutrients must have been quickly absorbed and metabolised due to the 'hidden hunger' in these semi-starved plants. This cannot be said for T_{12}, hence the poor effect of this treatment.

In the end, a generalisation that could be made for all the three batches commends itself for inclusion here. As mentioned earlier, the N-requirement of lettuce is high and it could be supplied either fully through the roots or partially supplemented by spray. However, the growth sustaining effect of nitrogen seemed to be offset more or less by the presence of phosphorus in the spray (T_3, T_7, T_8 and T_{12}). Similar conclusions about fertilizer or spray phosphorus have been drawn by other workers including Lundegårdh, 1951; Das, 1959; Mehrotra and Lal, 1970; Safaya, 1971 and Samiullah, 1971.

Like diameter (Table ~~18~~ 22), fresh weight of lettuce was also enhanced most by treatments T_{10} in plants sprayed early (10th week) and harvested either at 14th or 20th week after sowing first and second batch (Table ~~19~~ 23), with T_6 also giving a good performance. Again, treatments lacking NPK in the soil or N and P in the spray performed worst.

However, in plants sprayed late (14th week) and harvested at 20th week after sowing (third batch), treatment T_6 surpassed all other treatments with plants sprayed with water (T_5 and T_9) following it in this respect. The effect of T_{10}(which was equal to that of T_{11}) came next in descending order.

These observations support the earlier argument about the effect of treatments on the diameter of plants confirming the necessity and superiority of nitrogen for lettuce.

Finally, a glance at Table ~~19~~ 23 would show that plants of the first batch had the highest fresh weight and those of the third, the lowest. This commends the harvesting of lettuce at the earlier date as freshness is one of the essential criteria for marketability.

Table ~~20~~ 24 gives the affect of various treatments on dry matter production by lettuce. Like fresh weight, this attribute also was favoured by an early spray containing N (T_6 and T_{10}) irrespective of the stage of sampling. Barat and Das (1962) noted a similar effect in maize. However, in the third batch of plants sprayed late (14th week), spray of water (T_1, T_5 and T_9) had almost as good an effect as T_6.

It may be noted that (like fresh weight) plants of this batch also produced much less dry matter than even those of the first batch, harvested 6 weeks earlier. It seems justified to recommend, therefore, that late application of spray should be avoided in lettuce if dry matter (including minerals and other important constituents) are the criteria of quality.

The leaf composition of NPK was affected significantly by the treatments (Tables ~~21~~ 25 to ~~23~~ 27). Thus N concentration (Table 21) in all samples (whether harvested at 14th or 20th week after sowing) was increased mostly by N-containing sprays (T_2, T_6, T_8, T_{10} and T_{12}). This is in conformity with the findings of most workers (Wittwer and Teubner, 1959 and Anonymous, 1971). Similarly P concentration (Table ~~22~~ 26) was enhanced mostly by P-containing sprays (T_7, T_8, T_{11} and T_{12}). This confirms the work of earlier workers on fertilizer and spray application of phosphorus (Brenchley, 1929; MacLeod, 1969; Safaya, 1971; Samiullah, 1971).

A noteworthy feature of the leaf K concentration (Table ~~23~~ 27) was that it was generally higher than that of N or P. Moreover K concentration was highest in plants receiving full NPK through their roots (T_9 to T_{12}). This might be expected if the K requirement of lettuce were more than could be supplied by the soil alone or even by the addition of 1/2 NPK to the soil. Among these full NPK plants, the effect of spray treatments T_{10}, T_{11} and T_{12} was, however, critically different from that of T_9 (water spray) only in the first batch. In the other two batches of similar plants (receiving full basal NPK), a discerning feature was that T_9 had an effect equal to that of T_{11} and T_{12} but spray of nitrogen (T_{10}) resulted in a K concentration in leaves lower than even that in T_9, sprayed with water. Nitrogen, in this experiment, was sprayed as urea which is known to be hydrolysed enzymatically to ammonia in the leaves (Hinsvark et al. 1953; Boynton, 1954 and Wittwer and Teubner, 1959). Studies on the comparative effect of NO_3^-- and NH_4^+-nitrogen given through the roots (Dikussar, 1934; Nightingale, 1948; Drosdoff et al. 1955 and Safaya, 1971) reveal a synergistic effect of NO_3^-- and an antagonistic effect of NH_4^+-nitrogen on the leaf K concentration of a number of plants. Although not claiming a similar mechanism working in the leaves, it may be considered feasible that NH_4^+ ions generated by urea sprays there may have a similar effect in decreasing the K concentration in N-sprayed leaves. It may be pointed out that Barat and Das (1962) also noted a depressing effect of N-spray on the K concentration of maize.

In Experiment 3 on maize under field conditions, the effect of treatments on cob and grain yield, as well as on various fractions of carbohydrates and proteins in the grain, was significant (Tables ~~26~~ 28 to ~~36~~ 37).

There was general agreement regarding average yields of cob and grain between the data per plant and per hectare (Tables ~~26~~ 28 to ~~29~~ 31). It may be noted that the cob and grain yield response to T_1 (no fertilizer) was poorest, whereas, T_2 (1/2 N + 1/2 P + water spray) was also equally insufficient for grain production. Cob yield was superior in P-containing sprays (T_4, T_6 and T_7). However, T_8, which consisted of spray of N + P, was much inferior. It may be due to the detrimental effect of the higher total concentration in this treatment of the spray solution on the maize foliage.

Grain yield was also enhanced most by T_7 but, unlike cob yield, the N-containing spray (T_6) was also better than the rest of the treatments. Here also T_8 (N + P spray) gave a very poor performance, probably for the same reason as given above in the case of cob yield. The better effect of N- and P-containing sprays (T_6 and T_7) may be due to the fact that the three varieties of maize require much more fertilizer than was provided, developing thereby a "hidden hunger" which responded almost equally well to supplements of either of the two nutrients through the leaves.

In this connection it may be pointed out that while spray of nitrogen is well known to increase yields in maize (Klingman, 1957; Jones, 1959 and Singh and Sarohe, 1970) and in other cereals as reviewed by Wittwer and Teubner (1959), by Mehrotra and Lal (1970) and elsewhere (Anonymous, 1971), a similar beneficial effect of spray of phosphorus has also been recorded by Iliescu (1960) in maize and by Afridi and Samiullah (1973a) in barley.

Chemical analysis of the grain revealed that most of the carbohydrate and protein fractions were affected significantly by treatments (Tables ~~30~~ 32 to ~~35~~ 37). Regarding carbohydrates, the best effect on the soluble fraction was of spray of 1/2 N (T_3) followed by that of N (T_6), whereas insoluble and total carbohydrates were enhanced most by T_5 (the mixed dose of 1/2 N + 1/2 P). Among the protein fractions, insoluble and total proteins, which were affected significantly, were enhanced most by the spray of N but the effect was not of much consequence, under the conditions of the experiment, as it was equalled by the second control (T_2) grown with the same dose of basal dressing but sprayed with water only. A point to note in this connection is that whereas the insoluble and total carbohydrate percentage was lowest as a result of treatment T_1 (no fertilizer control) the insoluble and total proteins were depleted most by treatment T_5 (1/2 N + 1/2 P spray). Thus, treatment T_5 had a totally opposite effect on grain carbohydrate content as compared with the content of grain protein. Similar depressing effects on grain protein were noted in other P-containing spray treatments (T_4, T_7 and T_8).

Nitrogen spray is known to enhance grain protein content in cereals (Kuthy et al. 1952; Anma et al. 1954; Finney et al. 1957; Pavlov, 1960; Petinov and Pavlov, 1960; Gautam et al. 1964; Randhawa, 1969; and others). The detrimental effect of phosphorus in the spray confirms the data of Samiullah (1971) and Samiullah and Afridi (1975) on barley in which the grain protein content was found to be adversely affected enhancing its malting quality.

Differences among the three varieties of maize selected for this field trial were significant (Tables ~~26~~ 28 to ~~35~~ 37). It may, however, be pointed out that Ganga-5 (V_1) which was the highest yielder of cob and grain showed the lowest percentage of the carbohydrate and protein fractions in the grain. Of the other two varieties, Ganga-7 (V_2) was superior to Kisan (V_3) in yields. However, whereas the grain carbohydrate percentage of V_3 was more than V_2, the reverse held good for proteins.

The grains of Ganga-5 (V_1) are bolder, its 1,000 grain weight being 245 g as compared with 210 g for V_2 and 185 g for V_3. The low percentage of grain carbohydrates and proteins in variety V_1, therefore, seems to be due to dilution effect.

The results of the second field trial on maize (Experiment 4) were statistically significant. Like the first field trial, there was general agreement between the cob and grain yields per plant and per hectare (Tables 38 to 47). It may be recalled that there were three levels of basal fertiliser, namely, N + P, N + 1/2 P and 1/2 N + 1/2 P, and four of spray phosphorus, namely, 0, 1/2 P, P and 2P. Of these, only the effect of treatment T_8 (basal N + 1/2 P and spray of 2P) was clear-cut in the case of grain yields and percentage of insoluble and total proteins. T_8 increased these three characteristics, the effects being critically different from those of all other treatments. In addition T_8 enhanced almost all other characteristics also, but the effects were equal to those of several other treatments.

It seems that the N and P requirements of the varieties of maize were more or less met by full basal N and P application, with various doses of spray phosphorus having an additive effect. However, plants grown with full basal N but sub-optimal solid phosphorus (1/2 P) gave, a good account of themselves, in the presence of the highest dose of spray phosphorus (2P) of treatment T_8, to exhibit maximum effect. A comparable situation has been reported by Gautam _et al_. (1964) in maize and by Afridi and Samiullah (1973a) in barley. Spray of 2P may, therefore, be recommended with full basal N and 1/2 P in the case of maize for the sake of economy of phosphatic fertiliser which is in short supply.

It may be recalled that, as far as grain yield was concerned all treatments containing either spray of water (T_1 , T_5 and

T_9) or 1/2 N + 1/2 P in the soil (T_{10} to T_{12}) gave very poor results. This is understandable both from the view point of the overall good effect of spray phosphorus in the present experiment and the high fertiliser requirement of the selected varieties of maize.

Regarding grain carbohydrate and protein content, again T_8 was among the treatments that enhanced most of the fractions. However, this effect of phosphorus spray on protein is in contrast with the data of Samiullah (1971) and Samiullah and Afridi (1975) for barley. The reason for this discrepancy is not clear, but it may be due to differential effect of spray P on the protein metabolism of the two cereals.

In contrast, T_9 (basal 1/2 N + 1/2 P and spray of water) had the most adverse effect on the different characteristics. However, it may be noted that this deleterious effect was shared by a number of other treatments, particularly by T_{11} and by T_1, T_5, T_{10} and T_{12} in the case of yields, by T_7 for the carbohydrate fractions and by T_5 and T_{12} for the protein fractions in the grain.

Varietal differences in this experiment also were significant for all characteristics except cob yields. Variety Kisan (V_3) gave the best grain yield as a result of P sprays but Ganga-7 (V_2) shared this distinction with it, Ganga-5 (V_1) being the poorest yielder. The grain carbohydrate fractions were highest in Ganga-7 (V_2) with Ganga-5 having an equally high insoluble and total carbohydrate percentage. Ganga-7 (V_2) had the highest protein fractions also, which were lowest in Kisan (V_3).

A comparision of the data of Experiments 3 and 4, however, reveals that although there was a similarity of behavior among the three varieties regarding various protein fractions, the treatments modified the performance capacity of the varieties as far as grain yield and carbohydrate fractions were concerned. The reasons for these differences should not be sought in the present data. It seems desirable that work be extended to include observations on other grain characters, such as cob number per plant, grain number per cob and per plant, 1,000 grain weight etc. which are the characters contributing most to the yield and composition of the grain. Moreover, data collected at various stages of the development of the cob may also reveal the pattern of carbohydrate and protein fractions, as affected by various treatments.

CHAPTER VI

SUMMARY

A study of the effect of nitrogen, phosphorus and their combinations, on the growth, yield and NPK content of three varieties of barley (*Hordeum vulgare* L.), namely, RS 6 (V_1), IB 226 (V_2) and K 572/10 (V_3), and on one variety of lettuce (*Lactuca sativa* L.), namely, Suttons Golden Ball, was conducted in sand and soil culture, respectively during 1971-72. In 1973 and 1974, the effect of N, P and N + P on the yield and grain quality of three varieties of maize (*Zea mays* L.), namely, Ganga-5 (V_1), Ganga-7 (V_2) and Kisan (V_3) was studied under field conditions.

In the two pot experiments, different levels of nitrogen, phosphorus, and their combinations were applied as basal dressing as well as by foliar spray, according to a simple randomized block design, and the effect of these treatments was studied in sand culture in the three barley varieties (Experiment 1) and in soil culture in lettuce (Experiment 2).

Data for growth characteristics of plants and for the NPK concentration in the leaves were collected at heading and milky grain stages in barley and at 14th and 20th week after sowing in lettuce. Yield characteristics of barley were noted at harvest.

In the first field trial (Experiment 3), the effect of N, P and N + P applied in the soil and to the leaves, on yield

and grain quality of maize, was studied. In the second field trial (Experiment 4), emphasis was laid on the effect of different levels of spray phosphorus in combination with various levels of solid N and P. These two experiments were based on a factorial randomized design.

The data were subjected to statistical analysis and the main findings are summarised below experiment-wise:

<u>Experiment 1</u>. (<u>Sand culture : barley</u>)

1. At heading as well as milky grain stage, most of the growth characteristics were favourably affected in plants receiving full nutrition through their roots as compared with those receiving half the dose. However, the effect of sprays of N, P or N + P at 4th as well as 8th week after sowing was generally statistically equal to that of water sprays.

2. The yield characteristics of barley, in this experiment, were most favourably affected by full nutrient solution plus spray of nitrogen at 8th week after sowing. Among the plants receiving half strength of nutrient solution also, spray of nitrogen at 4th week after sowing gave higher ear and grain weight than other treatments, including spray of water.

3. Regarding varietal differences, shoot length and fresh weight were more in IB 226 (V_2); and the number of tillers and leaves, in K 572/10 (V_3) at both stages, whereas RS 6 (V_1)

occupied a middle position as regards these characteristics as well as dry weight at the milky grain stage which was highest in IB 226 (V_2).

4. Variety RS 6 (V_1) gave the best performance as regards ear and grain weight, with the other two varieties, showing equal yields, following it.

5. The effect of treatments at both stages of growth on the N concentration in leaves was significant but was statistically equal to that of spray with water.

6. At both stages, the effect of treatments on the P concentration in leaves was significant. However, at heading stage, spray of nutrients on plants grown with solutions of half strength showed better response generally as compared with spray of water; at the milky grain stage, the response to spray of nutrients was more prominent (but equal to that of controls) in the other batch of plants receiving full strength of nutrient solution.

7. The K concentration in leaves was significant only at the milky grain stage. The outstanding effect was that of nitrogen spray at 4th week after sowing on plants grown with full nutrient solution, most of the other treatments showing an effect equal to the controls.

8. With respect to varieties, the percentage of leaf N was highest in IB 226 (V_2) but equalled by RS 6 (V_1) and that of P

and K, in RS 6 (V_1) at the heading stage at which the response was significant. The N percentage in V_1 and V_3 and the P and K percentage in V_2 and V_3 were statistically equal.

Experiment 2. (Soil culture : lettuce)

9. In the second pot experiment on lettuce, the effect of treatments was significant. Diameter, fresh weight (yield) and dry weight were most favourably affected by the treatment T_{10} i.e. in plants grown with full NPK in the soil and sprayed with nitrogen. However, treatment T_6 i.e. 1/2 NPK in soil plus spray of nitrogen also showed good response for the above characters. Generally, plants grown without NPK added to the soil and sprayed with water grew poorly.

10. The percentage of nitrogen in leaves was high in plants sprayed with N (T_2, T_6, T_{10}) or N + P (T_{12}), the lowest value being recorded in plants sprayed with water only. However, the percentage of phosphorus and potassium in leaves was high when plants were sprayed with P (T_7, T_{11}) or N + P (T_{12}).

Experiment 3. (Field trial I : maize)

11. In the first field experiment on maize, the cob yield per plant and per hectare was increased most by the spray of P (T_7), 1/2 N + 1/2 P (T_8) or 1/2 P (T_4). The grain yield was, however, increased most by the spray of P (T_7) followed by that

of N (T_6). The lowest values for both characteristics were recorded in plants sprayed with water only (T_1 or T_2).

12. Variety Ganga-5 (V_1) performed best, with regard to the cob and grain yields, followed by Ganga-7 (V_2) and Kisan (V_3), in that order.

13. The soluble carbohydrate concentration in the grain was increased most by spray of 1/2 N (T_3) but the insoluble and total carbohydrate concentration was enhanced most by the spray of 1/2 N + 1/2 P (T_5). The lowest value for the soluble fraction was recorded in the treatment receiving 1/2 N + 1/2 P followed by spray of water (T_2); and that for the insoluble fraction as well as for total carbohydrate concentration in the other control grown without basal dressing and sprayed with water (T_1).

14. Kisan (V_3) performed best, among the three varieties, with regard to soluble, insoluble as well as total carbohydrate concentration in the grain. The performance of Ganga-5 (V_1) was poorest in this regard.

15. Spray of nitrogen in general enhanced the insoluble and total grain protein concentration, but the effect of mixed sprays of nitrogen and phosphorus was poor.

16. Variety Ganga-7 (V_2) had the highest percentage of various grain protein fractions and Ganga-5 (V_1), the lowest.

<u>Experiment 4</u>. (Field trial II: maize)

17. In the second field experiment on maize, the best cob yield per plant, as well as per hectare, was obtained by a number of treatments that performed equally well statistically. Among these spray of 2 P on plants grown with full basal N + 1/2 basal P (T_8) gave the highest (numerical) value. The same treatment (T_8) produced the highest quantity of grain per plant, as well as per hectare.

18. Varietal response regarding cob yields was non-significant but the total grain yield of varieties Kisan (V_3) and Ganga-7 (V_2) was better than that of Ganga-5 (V_1).

19. Treatments T_4, T_7 and T_{10} showed equally better effect on soluble carbohydrate concentration in the grain. The effect of treatments on the insoluble fraction as well as total carbohydrate concentration in the grain was significant but equal in 10 out of 12 treatments. It is, however, noteworthy that plants grown with full basal N + P and sprayed with water (T_1) gave the lowest value.

20. Varietal response was clear-cut for soluble carbohydrates only, the performance being Ganga-7 (V_2) Kisan (V_3) Ganga-5 (V_1). In the case of insoluble carbohydrates, Ganga-7 (V_2) and Ganga-5 (V_1) performed equally better than Kisan (V_3). As regards total carbohydrate concentration in the grain, the performance of Ganga-7

(V_2) and Ganga-5 (V_1) was equal on the one hand, followed by that of Ganga-5 (V_1) and Kisan (V_3), on the other.

21. The soluble protein fraction in the grain was statistically highest as a result of treatments T_1 (full basal N + P and sprayed with water), T_8 (full basal N + 1/2 basal P and sprayed with 2 P) and T_9 (half basal N + P and sprayed with water). Insoluble and total grain protein concentration was, however, highest in the treatment receiving full basal N + 1/2 P and sprayed with 2 P (T_8). It is noteworthy here that almost all treatments receiving 1/2 basal N performed poorly as regards the various protein fractions, irrespective of the spray applications.

22. Among the varieties, Ganga-7 (V_2) and Kisan (V_3) performed equally better than Ganga-5 (V_1) with respect to soluble protein concentration in grain. The pattern of performance for the insoluble and total grain proteins was Ganga-7 (V_2) $>$ Kisan (V_3) $>$ Ganga-5 (V_1).

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